IC HIGA
2 8 1951
NEERING
LIBRARY

APPLIED MECHANICS Reviews

A CRITICAL REVIEW OF THE WORLD LITERATURE IN APPLIED MECHANICS AND RELATED ENGINEERING SCIENCE

REVS. 4357-4677 VOL. 4, NO. 12 DECEMBER 1951

GENERAL

Theoretical and Experimental Methods.. 636
Mechanics (Dynamics, Statics, Kinematics) 638

MECHANICS OF SOLIDS

Gyroscopics, Governors, Servos..... 639
Vibrations, Balancing..... 639
Wave Motion, Impact..... 641
Elasticity Theory..... 641
Experimental Stress Analysis..... 642
Rods, Beams, Shafts, Springs, Cables, etc. 643
Plates, Disks, Shells, Membranes..... 643
Buckling Problems..... 644
Joints and Joining Methods..... 645
Structures..... 645
Rheology (Plastic, Viscoplastic Flow).... 648
Failure, Mechanics of Solid State..... 650
Material Test Techniques..... 650
Mechanical Properties of Specific Materials..... 651
Mechanics of Forming and Cutting..... 654

MECHANICS OF FLUIDS

Hydraulics; Cavitation; Transport..... 654
Incompressible Flow: Laminar, Viscous.. 655
Compressible Flow, Gas Dynamics..... 657
Turbulence, Boundary Layer, etc..... 660
Aerodynamics of Flight; Wind Forces... 662
Aeroelasticity (Flutter, Divergence, etc.). 665
Propellers, Fans, Turbines, Pumps, etc... 666
Flow and Flight Test Techniques..... 668

HEAT

Thermodynamics..... 669
Heat and Mass Transfer..... 671

MISCELLANEOUS

Acoustics..... 674
Ballistics, Detonics (Explosions)..... 676
Soil Mechanics, Seepage..... 676
Geophysics, Meteorology, Oceanography..... 677
Lubrication; Bearings; Wear..... 679
Marine Engineering Problems..... .. 680

Communications, 635

Recent Research on Creep of Engineering Materials, J. Marin, 633

Published Monthly by THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS at Easton, Pa., and edited by Midwest Research Institute with the co-operation of Linda Hall Library

APPLIED MECHANICS Reviews

Under the Sponsorship of

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS • SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS • INSTITUTE OF THE AERONAUTICAL SCIENCES • AMERICAN INSTITUTE OF PHYSICS • AMERICAN MATHEMATICAL SOCIETY • AMERICAN SOCIETY OF CIVIL ENGINEERS • AIR RESEARCH AND DEVELOPMENT COMMAND • THE ENGINEERING FOUNDATION • THE ENGINEERING INSTITUTE OF CANADA • THE INSTITUTION OF MECHANICAL ENGINEERS • MIDWEST RESEARCH INSTITUTE • OFFICE OF NAVAL RESEARCH

EDITOR	Martin Goland
EDITORIAL ADVISERS	T. von Kármán, S. Timoshenko
EXECUTIVE EDITOR	D. R. Mazkevich
ASSOCIATE EDITORS	J. C. Shipman, J. J. Jaklitsch, Jr., K. Zarankiewicz (Poland), Isao Imai (Japan)
ASSISTANT EDITORS	M. Garrett, H. K. Wilgus, S. Lechtman
EDITORIAL ASSISTANT	L. Graf
PUBLICATIONS MANAGER	S. A. Tucker
OFFICERS OF ASME	J. Calvin Brown, *President* J. L. Kopf, *Treasurer* C. E. Davies, *Secretary*
ASME MANAGING COMMITTEE	G. B. Pegram, *Chairman* H. L. Dryden, R. E. Peterson, LeVan Griffis, J. M. Lessells L. H. Donnell, *ASME Applied Mechanics Division*
ADVISORY BOARD	R. E. Peterson (ASME), *Chairman* R. D. Mindlin (SESA), *Secretary* K. O. Friedrichs (AMS), G. R. Rich (ASCE), K. S. M. Davidson (IAS), H. W. Swift (IME), J. J. Green (EIC), F. W. Bubb (ARDC), E. Bromberg (ONR)

Editorial Office: APPLIED MECHANICS REVIEWS, Midwest Research Institute, 4049 Pennsylvania, Kansas City 2, Mo., U.S.A.
Subscription and Production Office: The American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y., U.S.A.

HOW TO OBTAIN COPIES OF ARTICLES INDEXED: Photocopy or microfilm copies of all articles reviewed in this issue will be provided on request. Orders should specify the number and issue of APPLIED MECHANICS REVIEWS; should be addressed to APPLIED MECHANICS REVIEWS, Midwest Research Institute, 4049 Pennsylvania, Kansas City 2, Mo., and be accompanied by a remittance to cover costs. Photocopy costs are 25¢ for each page of the article photocopied, minimum charge $1; Microfilm costs include service charge of 50¢ per article, plus 3¢ per double page; minimum order, 75¢. *(Applicant assumes responsibility for questions of copyright arising from this copying and the use made of copies. Copyright material will not be reproduced beyond recognized "fair use" without consent of copyright owner.)*

APPLIED MECHANICS REVIEWS, December 1951, Vol. 4, No. 12. Published monthly by The American Society of Mechanical Engineers at 20th and Northampton Streets, Easton, Pa., U. S. A. The editorial office is located at the Midwest Research Institute, Kansas City 2, Mo., U. S. A. Headquarters of ASME, 29 West 39th St., New York 18, N. Y., U. S. A. Cable address: "Dynamic," New York. Price $1.50 per copy, $12.50 a year; to members of ASME and co-operating societies $0.75 per copy, $9 a year. Extra postage to countries not in the Pan-American Union, $1.50, to Canada, $0.75. Changes of address must be received at Society headquarters four weeks before they are to be effective on the mailing list. Please send old as well as new address. . . . By-Laws: The Society shall not be responsible for statements or opinions advanced in papers or printed in its publication (B13, Par. 4). . . . Entered as second-class matter, January 11, 1948, at the Post Office at Easton, Pa., under the Act of March 3, 1897. Copyrighted, 1951, by The American Society of Mechanical Engineers

APPLIED MECHANICS REVIEWS

VOL. 4, NO. 12 MARTIN GOLAND *Editor* DECEMBER 1951

A SURVEY OF RECENT RESEARCH ON CREEP OF ENGINEERING MATERIALS

JOSEPH MARIN

PROFESSOR OF ENGINEERING MECHANICS AND RESEARCH PROFESSOR OF ENGINEERING MATERIALS
THE PENNSYLVANIA STATE COLLEGE, STATE COLLEGE, PENNSYLVANIA

THE development of alloys capable of resisting high stresses at very high temperatures may be considered as one of the outstanding technical developments of the last decade. An important factor in the utilization of metals at high temperatures is their resistance to creep. Industrial and military uses of metals for elevated temperature applications have greatly increased. The selection of suitable alloys for steam and gas turbines and for equipment employed in the petroleum and various other chemical industries is often governed by the creep properties of the metal. For some materials used at normal temperatures, as for example, plastics, wood, and certain nonferrous metals, such as lead, creep may be a significant engineering design consideration.

The importance of high temperature and creep properties of materials in engineering design is reflected in the publication, during the past two years, of five books dealing with this subject (1, 2, 3, 4, and 5).* Research contributions to the study of creep may be classified according to experimental studies, theoretical developments, and applications. In this brief review, it will be possible to mention only some of the important publications in creep which have appeared during the past ten years.

EXPERIMENTAL STUDIES

Experimental studies have been aided in recent years by the development of new types of creep-testing equipment and new test techniques. Constant stress tension creep machines were developed to correct for changes in stress produced by changes in cross-sectional dimensions of specimens (6, 7). Dynamic creep-testing machines for determining creep under vibratory loads were devised to study the effect of dynamic loading conditions on creep (8, 9, 10). A number of new static creep-testing machines were developed for study of creep under stresses other than the usual tensile stress. Equipment was developed for compression creep tests (11, 12) for pure torsion, bending, and for column creep studies (13).

Numerous investigations have been conducted in recent years on both ferrous and nonferrous metals and alloys to study the influence of metallurgical variables, temperature, or type of stress on the creep properties and creep rupture strength. Some of these studies are listed under (14) to (22). The creep of nonmetallic materials, including ceramic bodies (23) and glass (24), have been studied. The influence of a combined state of stress on creep deformation for a low carbon steel and aluminum alloys was investigated by using tubular specimens subjected to combined torsion and tension (25, 26). A number of investigations to determine the creep properties of various plastics subjected to various stresses were also conducted (27, 28, 29, 30). Other experimental studies on creep are summarized in (1) to (5).

THEORETICAL DEVELOPMENTS

Theories of both the mechanistic and phenomenological types have been proposed in an attempt to explain the behavior of materials when subjected to creep. Theories of the activation energy and rate process type were applied to creep (28, 31, 33, 34). In an attempt to understand the mechanism of creep, the dislocation theory was applied to creep (32). Various investigators (36, 37) also considered further both the strain-hardening and time-hardening creep laws. A mechanical equation of state for creep was formulated (38) and applied to plastics (39). In an attempt to predict creep life to rupture, a theory was developed considering creep as a diffusion process (40). The foregoing theories and others are completely discussed in (1, 3, 4, and 5). Creep rate-stress relations for combined states of stress, as determined in (25) and (26), were found to agree with the Soderberg-Odquist theory for creep under combined stresses. A number of new empirical creep-stress-time relations were also proposed for use in interpreting test data.

ENGINEERING APPLICATIONS

Engineering-type creep theories have been applied to obtain stresses and deformations in various kinds of structural and machine members. Stress and strain for creep loading conditions have been obtained for thick-walled cylinders subjected to internal pressure (41), bending and torsion of bars (42, 30, 43, 44), and rotating disks (45). Several theories for predicting creep relaxation stress conditions based on constant stress relations were also developed (46, 47, 37, 35). A finite difference method

* Numbers in parentheses refer to Bibliography at end of the paper.

EDITOR'S NOTE: The twelfth in a series of articles, contributed to APPLIED MECHANICS REVIEWS by international authorities, surveying important topics in applied mechanics.

was applied to determine stresses in gas-turbine disks subjected to plastic flow and creep (48).

Although these engineering theories for creep stress and strain are based on assumed empirical relations between the creep time and stress, they afford, at the present time, the only means by which creep can be considered in design.

BIBLIOGRAPHY

1 Clark, F. H., Metals at high temperatures, AMR **4,** Rev. 2065.

2 Rotherham, L. A., Creep of metals, AMR **4,** Rev. 3866.

3 Smith, G. V., Properties of metals at elevated temperatures, AMR **3,** Rev. 1944.

4 Stanford, E. G., The creep of metals and alloys, AMR **3,** Rev. 1932.

5 Sully, A. H., Metallic creep, AMR **4,** Rev. 205.

6 Andrade, E. N. da C., Viscosity and plasticity, Cambridge, England, W. Heffer and Sons, Ltd., 1945.

7 Ward, A. G., and Marriott, R. R., A constant stress apparatus for the study of the creep properties of plastics, *J. sci. Instrum.* **25,** 5, 147–151, 1948.

8 Lazan, B. J., Dynamic creep and rupture properties of temperature-resistant materials under tensile fatigue stress, AMR **4,** Rev. 1608.

9 Manjoine, M. J., Effect of pulsating loads on creep characteristics of aluminum alloy 14S-T, AMR **4,** Rev. 693.

10 Greenwood, J. N., The influence of vibration on the creep of lead, AMR **4,** Rev. 258.

11 Sully, A. H., Compression creep testing, *Metal Industry* **75,** 1949.

12 Marin, J., Pao, Y. H., and Cuff, G. E., Creep properties of lucite and plexiglas for tension, compression, bending and torsion, Rev. 4466 in this issue.

13 Marin, J., Creep deflections in columns, AMR **4,** Rev. 246.

14 Andrade, E. N. da C., Creep of metals and recrystallization, *Nature* **162,** 4115, p. 410, 1948.

15 Chevigny, R., and Syre, R., Creep of aluminum alloys, AMR **4,** Rev. 257.

16 Clark, C. L., and Freeman, J. W., The apparent influence of grain size on the high temperature properties of austenitic steels, *Trans. Amer. Soc. Metals* **38,** 19, 148–179, 1947.

17 Dorn, J. E., and Tietz, T. E., Creep and stress-rupture investigations on some aluminum alloy sheet metals, AMR **4,** Rev. 701.

18 Frey, D. N., The general tensional relaxation properties of a bolting steel, Rev. 4468 in this issue.

19 Glen, J., The creep properties of molybdenum, chromium-molybdenum and molybdenum-vanadium steels, *J. Iron Steel Inst. Lond.* **158,** 37–80, Jan. 1948.

20 Symposium on materials for gas turbines, *Proc. Amer. Soc. Test. Mat.* **46,** 1946.

21 Tapsell, H. J., and Wood, W. A., Mechanism of creep in aluminum, *Nature* **158,** 4012, 415–416, 1946.

22 Symposium on high-temperature steels and alloys for gas turbines, Iron and Steel Institute, London, Feb. 1951.

23 Burdick, M. D., Moreland, K. E., and Geller, R. F., Strength and creep characteristics of ceramic bodies at elevated temperatures, AMR **3,** Rev. 503.

24 Crussard, C., The creep of glass at high temperatures, *Sheet Metal Indust.* **25,** 2471–2474, Dec. 1948.

25 Johnson, A. E., Some aspects of the behavior of a low carbon steel and an aluminum alloy under complex stress systems at elevated temperatures, *Proc. seventh int. Congr. appl. Mech.*, London, Sept. 1948.

26 Marin, J., Faupel, J. H., and Hu, L. W., Combined tension-torsion creep-time relations for aluminum alloy 2S-O, Rev. 4467 in this issue.

27 Findley, W. N., and Worley, W. J., Mechanical properties of five laminated plastics, AMR **2,** Rev. 65.

28 Findley, W. N., Adams, C. A., and Worley, W. J., The effect of temperature on the creep of two laminated plastics as interpreted by the hyperbolic-sine law and activation energy theory, AMR **2,** Rev. 1513.

29 Staff, C. E., Quackenbos, H. M., Jr., and Hill, J. M., Long-time tension and creep tests of plastics, AMR **4,** Rev. 1586.

30 Marin, J., Static and dynamic properties of laminated plastics for various types of stress, AMR **1,** Rev. 1366.

31 Machlin, E. S., and Nowick, A. S., Stress rupture of heat resisting alloys as a rate process, *Metals Technology* **14,** 2, Feb. 1947.

32 Nowick, A. S. and Machlin, E. S., Dislocation theory as applied by N.A.C.A. to the creep of metals, *J. appl. Phys.* **18,** 1, 79–87, 1947.

33 Orowan, E., Creep of metals, *J. West. Scotland Iron and Steel Inst.* **54,** 1947.

34 Smith, C. L., A theory of transient creep in metals, AMR 2, Rev. 49.

35 Nadai, A., Strain hardening and softening with time in reference to creep and relaxation in metals, 1950 ASME Annual Meeting Paper No. 50—A-121, in *Mech. Engng. tech. digest,* April 1951, p. 335.

36 Robotnov, Ya. N., Evaluation of machine parts for creep (in Russian), AMR **3,** Rev. 67.

37 Roberts, I., Correlation of tensile creep tests with relaxation tests, AMR **3,** Rev. 1696.

38 Hollomon, J. H., The mechanical equation of state, AMR 1, Rev. 63.

39 Findley, W. N., The mechanical equation of state with special attention to the creep of plastics, AMR **4,** Rev. 2516.

40 McCance, A., The plastic behavior of solids, AMR **3,** Rev. 2649.

41 Coffin, L. F., Shepler, P. and Cherniak, G., Primary creep in the design of internal pressure vessels, AMR **3,** Rev. 2641.

42 Kachanov, L. M., On the theory of transient creep (in Russian), AMR **3,** Rev. 1096.

43 Marin, J. and Cuff, G., Creep-time relations for polystyrene under tension, bending and torsion, AMR **4,** Rev. 246.

44 Popov, E. P., Bending of beams with creep, AMR **2,** Rev. 1252.

45 Popov, E. P., Stresses in turbine disks at high temperatures, *J. Franklin Inst.* **243,** 5, 1947.

46 Popov, E. P., Correlation of tension creep tests and relaxation tests, *J. appl. Mech.* **69,** p. A-135, 1947.

47 Davis, E. A., Relaxation of stress in heat exchanger tube of ideal material, 1950 ASME Annual Meeting Paper No. 50—A-122, in *Mech. Engng. tech. digest,* April 1951, p. 335.

48 Millenson, M. B. and Manson, S. S., Determination of stresses in gas turbine disks subjected to plastic flow and creep, AMR **3,** Rev. 1071.

Communications

Concerning AMR 4, Rev. 2865 (July 1951): I. Malkin, Stress analysis of a hemispherical pressure vessel head under concentric line loads.

The concluding sentence of the review may create the impression that the reviewer is indicating a simpler way of solution. He states that, in the author's analysis, "the problem is set up by taking all loads simultaneously into consideration," while the "author's solution can actually be obtained by the superposition of several simple solutions each involving only one load at a time." By simple solutions he evidently means solutions with *two* constants of integration; such solutions are to be used in the case of a single load line. Let us see now what changes would be produced by the procedure which the reviewer recommends. The entire work done in the analysis up to the system (39) to (42), inclusively, remains virtually unaffected except that the Eq. (34) become invalid and with the difference that the constants of integration will appear in the formulas (31) and (39) to (42) not in pairs, but in singles; in other words, the system (39) to (42) gives the formulas for the computation of the integration constants of the simple solutions *immediately*. Formula (47) remains unchanged and the remaining two integration constants of the spherical head are to be determined together with the cylinder constants M_0, Q_0 from the system (49) to (55) essentially in the same manner as in the author's analysis. So the only advantage of the suggested modified procedure is a simpler determination of the constants of the simple solutions. But after having determined the latter constants, they must be collected at each loading circle, which cannot lead to anything else but the set of formulas (43a) to (46a) of the analysis. The trifling simplification won in the solution of the system (39) to (42) is of no use, because the solution of the problem is given by the formulas (43a) to (46a); *these* are the expressions which have to be figured out numerically, no matter whether they are being arrived at as in the analysis, or by the superposition of simple solutions. This consideration shows that the reviewer's suggestion does not imply any improvement nor virtually any changes in the author's procedure of solution; in the best case, it contains only a certain modification of the mechanical interpretation of the procedure used in the analysis.

I. Malkin, USA

Concerning AMR 3, Rev. 2268 (Nov. 1950): W. D. Mitchell and D. Rosenthal, Influence of the elastic constants on the partition of load between rivets.

I should appreciate it if the following misstatements were brought to the attention of your readers. The reviewer says:

"After substituting bolts for rivets, authors appear to have measured over-all displacement of their double-lap joint with one leg of extensometer on a part of joint almost certain to have been affected by local deformations. Data obtained appear then to have been analyzed by an electric analog using quantities of doubtful validity, since computed deformation-of-bolt factors from which pertinent resistances were determined were shown to be in poor agreement with the experimental."

Apparently the reviewer is not aware of the facts that: (1) The effects of local deformation on one leg of the extensometer have been taken care of in the analysis by an appropriate term dealing with the end portion of the plate (the resistance R_3 in the electric analog); and (2) the analysis by means of the electric analog has nothing whatsoever to do with the "poor" agreement between the experimental and computed deformation-of-bolt factors. As pointed out on page 22 of the paper, the object of the analysis was to check the assumption that the load deformation ratio for a particular rivet and joint element was independent of the number of rivets in the joint. The validity of this assumption must be judged on the basis of Table II and not Table III, which the reviewer apparently has used for his statement. The computed and experimental values of Table II agree within better than 3%. Two joints show a discrepancy of 7.5% and 10%, respectively. This can be accounted for by the experimental behavior of these joints.

The reviewer seems to have missed the point of the paper which was precisely to bring out the "poor" agreement between the experimental and computed deformations-of-bolt factors, thus justifying the conclusions. Strangely enough, the reviewer considers the conclusions to be reasonable, but nevertheless criticizes the paper. These conclusions are:

"1 In order to improve substantially the partition of load between the rivets in a line, the latter must be made of a material which is at least ten times less rigid than the material of the joined members."

"2 In heterogeneous structures, predictions based on the ratio of moduli of elasticity may be at fault because of restrictions imposed on the magnitude and nature of deformation of the less rigid elements by the more rigid ones."

Before concluding, I should like to raise one more point: The reviewer seems to be unable to check "doubtful" procedures, assumptions, or conclusions because the description of the extensometer is lacking in essential details. The only detail pertinent to the extensometer is that given in Fig. 3. The rest of the equipment is of a standard commercial type as indicated in the paper, footnote**. Therefore, the precision of the extensometer is that of the commercial equipment (±10 microin.) which is believed to be known to most present-day experimental-stress analysts. The addition of a mechanical lever, Fig. 3, can only affect the reproducibility of readings because of friction and loose fit. These points have been checked by means of a supermicrometer. The reproducibility of the results can also be judged from diagrams 4 to 6 which, as usual, cumulate several readings made on loading and unloading.

D. Rosenthal, USA

Concerning AMR 4, Rev. 3798 (Oct. 1951):

The paper by D. Radenković is in French.

Concerning AMR 4, Rev. 3174 (Aug. 1951): M. M. Frocht assisted by D. Landsberg, Factors of stress concentration in bars with deep sharp grooves and fillets in tension.

To further clarify the question of accuracy of photoelastic work, reviewer wishes to make the following statement: From author's estimate, for $r/d \geq 0.05$, probable error is within 2 to 3%; this error increases as r/d decreases, reaching 5 to 10% for $r/d \leq 0.02$.

A. M. Wahl, USA

Concerning AMR 4, Rev. 2842 (July 1951): C. N. Zangar and H. B. Phillips, Photoelastic interferometer determination of stresses around an inspection gallery.

It is desired to comment on the reviewer's interpretation of the procedures involved as it relates to the following: (1) Creep in the model material is negligible since the model is loaded and unloaded for the reading at each point, in a cycle of about 20 seconds. (2) Initial stress such as time-edge stress can exist in a model without effect on the interferometer results, since the instrument measures the change in stress due to an applied load. Interferometer readings are taken to within 0.05-inch of an edge, and the boundary stresses are confirmed with a polariscope study, in which case care is taken to avoid time-edge effects. A three-months' study of a model showed no noticeable differences in interferometer readings with time. (3) Although the method is a point-by-point analysis, the comment that it is time-consuming is unfounded when compared with other methods of obtaining stresses at interior points.

After nominal training, observers can read between 200 and 250 points in an 8-hour day. This is usually more than enough points to analyze the problems normally encountered.

In correspondence with the reviewer, agreement has been reached on these remarks.

C. N. Zangar and H. B. Phillips, USA

Theoretical and Experimental Methods

(See also Revs. 4429, 4617, 4628, 4633)

4357. Hartree, D. R., Automatic calculating machines (in German), *Z. angew. Math. Mech.* **31,** 1/2, 1–12, Jan./Feb. 1951.

This is an expository article dealing with the following topics: Babbage's Analytical Engine; structure of calculating machines; brief descriptions of the Mark I at Harvard, the ENIAC at Aberdeen Proving Ground, and the EDSAC at Cambridge, England; and a discussion of programming and coding relative to a simple example. Harry D. Huskey, USA

4358. Wells, A. A., On the solution of beam-on-elastic-foundation problems by means of a mechanical analogue, *Instn. mech. Engrs. appl. Mech.* (*W.E.P.* no. 62), **163,** 307–310, 1951.

Paper deals with use of apparatus to determine deflection curve of beam on elastic foundation. Examples cited are (*a*) elastically supported beam carrying normal concentrated force at center of long span, and (*b*) deflection in section of full head of pressure vessel with rotational symmetry.

Apparatus is a simple mechanism. Piano wire is used for beam; loads and reactions are applied at regular intervals along suspended wire beam, producing transverse deflection of the wire.

Experimental results in example (*a*) agree very well with analytical solution of differential equation. Test results from strain gage measurements on actual drum of same dimensions as pressure vessel in example (*b*) are in good agreement with results obtained from analog. D. E. Hardenbergh, USA

4359. Balaca, A. P., Mathematical considerations on material testing (in Spanish), *Informes Construc.* **3,** 25, 26; 6 pp.; 7 pp.; Nov., Dec. 1950.

Paper deals with statistical considerations about the presentation of experimental data. After reviewing fundamental concepts, author gives a nomograph to simplify some of the mathematical computations and shows its use in two examples.

A. J. Durelli, USA

4360. Dumas, M., and Maheu, P., Statistical methods and their application in the field of industrial techniques, III (in French), *Mémor. Artill. fr.* **24,** 4, 765–850, 1950.

Authors discuss some of the mathematics which are useful in the application of statistics to concrete problems. Among other things, a number of common series expansions are given and some practical methods are described for interpolation, summation of series, and numerical evaluation of integrals. Also, the incomplete beta and gamma distributions are described in some detail. A number of useful tables are given in the appendix; these include logarithms of factorials, normal areas, and tables related to the incomplete beta and gamma distributions.

Benjamin Epstein, USA

4361. Zurmühl, R., Matrices, a treatment for engineers [Matrizen eine darstellung für ingenieure], Berlin, Springer-Verlag, 1950, xiv + 427 pp., 25 figs. DM 25.50

This book, directed toward the engineer, is an elementary exposition of the general theory of matrixes. The author presupposes only a limited mathematical background and deals with those topics which are most useful in the application of the theory to problems in the engineering sciences. The writing is clear and the text contains many examples which help the reader to understand the general theory. Reviewer likes particularly the systematic use of the notion of a finite matrix as a linear transformation over a finite dimensional vector space.

The first chapter introduces the general elementary theory of matrixes and vector spaces. Chapter 2 deals with the rank of a matrix and includes sections on linear independence and linear equations. Chapter 3 discusses the connection between quadratic forms and linear transformations. The general eigenvalue problem is treated in the fourth chapter and sections deal with the more special problem of diagonalizing a symmetric matrix. The fifth chapter deals with the structure of a matrix and contains the Cayley-Hamilton theorem as well as the Jordan normal-form theorem. Chapter 6 deals with numerical methods and chapter 7 contains applications to physical problems. The last chapter also contains a section on tensors.

The book as a whole is well balanced and is recommended for those who want an easy introduction to the theory of matrixes.

A. Devinatz, USA

4362. Schmeidler, W., Lectures on determinants and matrices with application in physics and engineering [Vortäge über Determinanten und Matrizen mit Anwendungen in Physik und Technik], Berlin, Akademie-Verlag, 1949, viii + 155 pp. DM 10.

Encouraged by the popularity and success of "Elementary Matrices" by Duncan, Frazer and Collar, an increasing number of mathematicians during the last decade have left their high pedestal and condescended to explain to the engineer in more practical terms what matrixes are useful for. The texts on matrixes available even two decades ago, such as the "Introduction to Higher Algebra" by Bôcher, disdained even to mention that matrixes can be used, among others, to solve differential and integral equations. The technical reader was hopelessly discouraged and lost in a maze of bilinear forms and elementary divisors, without being able to see how all that seemingly wasted brain power could be used.

The present book is intended as an introduction to matrixes, written with one eye fixed upon the needs of the student of physics and engineering, but with the other eye still anxiously focused on the approval of the professional mathematician. The result is a satisfactory treatise for the benefit of the more advanced technical student who is looking beyond a mere formal technique of manipulation.

The starting point is upon the elementary level of determinants, solution of linear equations with Cramer's rule, and manipulation with matrixes and vectors. Linear transformations and the normalization of quadratic and Hermitean forms follow, with practical methods given for finding the eigenvalues and eigenfunctions of a Hermitean matrix. A chapter is devoted to quick methods for solving a set of linear algebraic equations, and another chapter discusses several suggested criteria for determining whether an algebraic equation has all negative real or positive imaginary roots. The closing chapters treat the differentiation and integration of matrixes and the solution of a set of simultaneous differential equations with constant, variable, and periodic coefficients. The accompanying practical illustrations—rather few in number—are taken from the fields of mechanical linkages, stationary electric circuits, and mechanical vibrations.

Besides solving the already established *linear* algebraic and differential equations, there exist at least two other fields of technical endeavor in which matrixes play an important role. One is the *solution* of the dynamical equations of Lagrange and of those

derived from a variational principle. The other territory includes the *setting up* of the equations of complex dynamical systems. Since the organization of dynamical procedures involves an invariant point of view which submerges the identity of a matrix within the personality of the more advanced concept of "tensor," this book avoids those extensions and stays within the limited scope stated in its title. Gabriel Kron, USA

4363. Jaeckel, K., Error compensation in functions with parametric representation (in German), *Z. angew. Math. Mech.* **31**, 6, 185–186, June 1951.

Author considers the correspondence $y = y(x)$ where $x = f(t, u)$ and $y = g(t, u)$, with t a parameter which cannot be eliminated, and u a single constant. The values $x = X_\nu$, $y = Y_\nu$, $\nu = 1, 2, \ldots, n$ are given. The problem is formulated for minimum error between $y_\nu = g(t_\nu, u)$ and Y_ν under the side condition $f(t_\nu, u) = X_\nu$. For complicated functional dependence between t_ν and u, the problem is linearized by perturbations on these quantities.
R. M. Rosenberg, USA

4364. Fischer, O. F., Universal mechanics and Hamilton's quaternions, Stockholm, Axion Institute, 1951, vi + 356 pp. $10.

The author contends that the whole of mechanics is best understood in terms of hypercomplex numbers. He calls his book a "cavalcade," in that he is content to sketch many topics in a more or less isolated way, rather than, as might be suggested by the title, attempting to formulate a universal structure of mechanics from which the various special disciplines are derivable. His viewpoint is purely formal and algebraic, and the common feature he finds in many disciplines consists in their susceptibility to a treatment in terms of hypercomplex operations.

Toward the middle of the book and thereafter the emphasis is put upon the unified field theories of Weyl, Einstein (1950), Eddington, Mie, and Küssner, with some of the author's own ideas on this subject. The notation becomes elaborate, and the exposition is difficult to follow.

While there are many evident shortcomings in this book, the reader will appreciate the author's unpretentious sincerity and earnest attempts to master a difficult and profound subject. "This is a book written by a civil engineer on universal mechanics with an attempt to introduce a certain order in its mathematical structure by means of Hamilton's quaternions. . . . I have called the book a 'cavalcade,' indicating a rather erratic path of approach. . . . But the logic of the quaternion calculus also has inspired entirely new trends of thought. *The book is full of loose ends*, hardly started yet and open to development by better investigators. . . . My chief interest has been to establish a platform from which future investigations may be easier to develop, and to show that an important means of clarifying the existence of 'trunk lines' of natural philosophy may well be the calculus of Hamilton's quaternions." C. Truesdell, USA

4365. Bisplinghoff, R. L., Pian, T. H. H., and Levy, L. I., A mechanical analyzer for computing transient stresses in airplane structures, *J. appl. Mech.* **17**, 3, 310–314, Sept. 1950.

The mechanical analyzer is a combination of simple torsion pendulums and a system of electronic pickups. Transient stresses in structures with many degrees of freedom may be obtained (a) by adjusting the frequencies of the torsional pendulums to correspond to the normal modes of the complete structure, (b) by adjusting the input linkages to give the appropriate relative magnitudes for the generalized forces, and (c) by recording the transient stresses under consideration from the pendulum motion after proper amplification. An example showing the response of a system with three degrees of freedom subjected to a half-sine wave excitation indicates excellent agreement between analytical calculations and test results. Conrad C. Wan, USA

4366. Luke, Y. L., Flake, G., and Jones, G., Tables of the incomplete Bessel function $j_n(\mu, \theta) = {}_0\int^\theta e^{i\mu\cos\theta}\cos n\theta d\theta$, Midwest Res. Inst., Kansas City, Mo., 6 pp., 12 tables, 1951.

Report gives values of above function for $n = 0, 1, 2$ and various values of $\cos\theta$. Tables of other functons used in evaluating above are also included. Tables are useful for calculating aerodynamic flutter coefficients in subsonic flow. Ed.

4367. Ricci, L., Table of roots of low modulus of an equation of interest to the science of structures (in Italian), *Riv. Ingegn.* no. 2, Feb. 1951 = *Cons. Naz. Richer.* no. 296, 8 pp., 1951.

Equation $kz = \pm \sin z$, for fixed k, arises in the study of equilibria of elastic bodies. For $k = 0.10\ (0.01)\ 1.00$, author tabulates real and imaginary parts of all roots for which real parts do not exceed 10π in magnitude. Values are given to 4 and sometimes 5 decimals. Also included are a description of method of computation and asymptotic formulas for both components in terms of the order, roots being ordered according to increasing real parts.
A. S. Householder, USA

4368. Head, J. W., The solution of Lagrangian frequency equations with complex coefficients or roots by the escalator method, *Aircr. Engng.* **22**, 254, 104–105, 108, Apr. 1950.

Escalator method was developed by author and J. Morris for finding characteristic roots and vectors of matrixes, as required in determining flutter frequencies, etc. Method consists of treating in succession, 2×2, 3×3, . . . submatrixes formed by stroking out rows and columns of the original matrix. At each stage, roots and vectors are used to find an equation for characteristic frequencies of next higher stage, this equation being expressed in a form convenient for solution. Paper shows how the escalator method is applied when matrix elements and roots are complex. Reviewer feels method is interesting in some special problems where lower approximations leave the matrix unchanged except for bordering rows and columns. In general, it is less simple than iteration and other methods, and not easily adapted to automatic machines. C. C. Gotlieb, Canada

4369. Kats, A. M., On the criterion of aperiodic stability (in Russian), *Prikl. Mat. Mekh.* **15**, 1, p. 120, Jan.-Feb. 1951.

Conditions are investigated under which a polynomial characteristic equation has only real roots with negative real parts. A set of determinantal inequalities is obtained as being necessary and sufficient. Using a theorem of Michaelov, the derivation is simpler in form than that given by Meerov in 1945. The determinants are also exhibited in a second form, obtained manipulatively from those first obtained. Robert E. Roberson, USA

4370. Bubb, F. W., A new linear operational calculus, *Wright-Patterson Air Force Base, Dayton, AF tech. Rep.* 6581, v + 30 pp., May 1951.

Author considers the ordinates of a time function $F(t)$ at moments $(t - nv)$ equally spaced a time v apart. If each ordinate multiplies an even bell-shaped function of maximum unity (interpolating function), the sum $f(t)$ of a finite number of such terms will approximate $F(t)$. Author adopts as interpolating function $(\sin \pi t/v)/(\pi t/v)$. He then defines as P-transform of $F(t)$ the polynomial $F(t - nv)x^n$, where n takes all positive, zero, and negative values within specified limits. He shows that to the classical relation (convolution integral) between the input, the memory and the response of a linear system corresponds in the x-domain a simple multiplication between P-transforms. It ap-

pears from the numerical examples given that, at the cost of deliberately introducing an error (which can be made as small as desired), author has succeeded in replacing the continuous functions of classical physics by impulse sequences which are ideally suited for mechanical computation. Moreover, the P-transformation and its inverse, being defined by simple operations on real variables, make no use of contour integration and are thus fundamentally simpler than Fourier or Laplace transforms. The method seems very promising. P. Le Corbeiller, USA

4371. Bubb, F. W., Linear noise smoothing and predicting filters, *Wright-Patterson Air Force Base, Dayton, AF tech. Rep.* 6586, iv + 22 pp., May 1951.

Paper begins with an abbreviated but clear presentation of the new operational calculus proposed by the author [see preceding review]. This calculus is then applied to the problem of designing the best smoothing and predicting filter to be used in connection with a gunfire control system. The method of solution is that of N. Wiener in his book "Extrapolation, interpolation and smoothing of stationary time series" (Wiley, 1949), much simplified in presentation by the author's system of replacing a continuous time function by a limited sequence of equidistant impulses. The problem is then to obtain a specified number of ordinates of the "best" memory function (minimum mean-square error), the data being correlation coefficients (not functions) of signal plus noise and correlation coefficients of input signal and delayed output signal. The paper works out a numerical case of a simple example treated in Wiener's book and compares the approximate result from P-transform analysis with Wiener's rigorous solution. This excellent paper and its companion (AF 6581) are highly recommended. P. Le Corbeiller, USA

4372. Herni, H., Prof. Dr. Paul Schäpfer—Prof. Dr. Mirko Roš—Life and work (in German), *Eidgenöss. Mat.Prüf.Anst.*, 32 pp., 1950.

Life and work of the president and of the director of the Federal Materials Testing Laboratory and Research Institute in Zurich (EMPA), published on the occasion of their retirement in Sept. 1949. Very valuable are the complete lists of publications of both these leading authorities in the field of research and testing engineering materials. J. J. Polivka, USA

4373. Arnoldi, W. E., The principle of minimized iterations in the solution of the matrix eigenvalue problem, *Quart. appl. Math.* **9,** 1, 17–29, Apr. 1951.

Paper presents Lanczos' method of minimized iterations [AMR 4, Rev. 2339] in modified form. To obtain eigenvalues λ, modal columns k and modal rows κ of matrix u (degree n), a reduced matrix (degree m; $m \leq n$) is established by aid of expansions into arbitrary vectors

$$k = \sum_{i=1}^{m} c_i k_i \quad \text{and} \quad \kappa = \sum_{i=1}^{m} \gamma_i \kappa_i \qquad [1]$$

For $m \to n$, eigenvalues of reduced matrix will converge to λ, while modal columns c and rows γ of this matrix yield by intermedience of [1] vectors converging to k and κ. If, for $i \neq j$, conditions $\kappa_j k_i = 0$ are satisfied, the characteristic equation of reduced matrix can easily be established. Simple formulas for generation of biorthogonal vector sets k_i, κ_i are given. For each further iteration step m is increased by 1.

Author considers application to Galerkin's method, where κ_j is identified with k_j', leading to $k_j' k_i = 0$ for $i \neq j$. It is shown that this method has the advantage of requiring only half the number of matrix-column products compared with Lanczos' method. However, reviewer remarks that for nonsymmetric matrixes the number of exact figures in each approximated eigenvalue will also be halved, comparing same values of m in each method.

Nonhomogeneous problem $(\lambda I - u)\, k = q$, with I unit matrix and k unknown vector (λ and q specified), is treated in a similar manner. A. I. van de Vooren, Holland

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 4369, 4396, 4488, 4571, 4642, 4674)

4374. Inglis, Sir Charles, Applied mechanics for engineers, New York, Cambridge University Press, July 1951, xii + 404 pp. $7.50.

Book presents material for a two-year course in statics, dynamics, and vibrations for upper-class engineering students and, in reviewer's opinion, must rate as one of finest books to appear with this objective. A few three-dimensional topics are discussed but emphasis is placed mainly upon planar problems. In addition to traditional topics author discusses truss deformations, taut wires, vibration of beams and vehicles, harmonic analysis, and certain nonlinear topics (e.g., external ballistics, vibrations). Mathematical prerequisites generally do not extend beyond integral calculus, and Lagrange equations are not discussed. Step-by-step methods and approximations are used in the nonlinear problems and in discussion of taut wires. Some knowledge of fundamental principles is presupposed. This permits author to present underlying theory and method of solution of each problem in an economical, yet lucid manner. Each topic is illustrated by an exceedingly practical numerical example which will assure the student as to the fruitfulness of his study. Teachers will appreciate number and quality of problems for assignment but may be mildly disturbed by author's failure to identify graphical and analytical methods of computing deflections with the names of Williott and Castigliano, and by failure to use accepted symbols for partial derivatives. Author's formula and calculations of wind pressures on page 151 are in error. John E. Goldberg, USA

4375. Federhofer, K., On the inertia pole of a rigid system in plane motion and the inertia pole curve of a central crank mechanism (in German), *Öst. Ing.-Arch.* **5,** 3, 240–245, 1951.

For a link in constrained plane motion, with given rotopole (instant center), turning pole (Wendepol), center of gravity and centroidal radius of gyration, the "inertia pole" is the common point of intersection of the inertia force vectors for all possible states of acceleration. Author derives an algebraic expression for the position of this pole; this is useful in supplementing graphical methods and in determining the path of the inertia pole during a complete mechanism cycle.

Results are applied to the example of a slider-crank mechanism. Coordinates of the inertia pole of the connecting rod, in a reference system fixed to the rod, are evaluated numerically; during one cycle, the pole moves approximately along a straight line perpendicular to the rod. Results are exhibited for the center of gravity at and near the connecting rod midpoint.

G. A. Nothmann, USA

4376. Bereis, R., Outline of a theory of plane motion based on complex numbers (in German), *Öst. Ing.-Arch.* **5,** 3, 246–266, 1951.

Paper gives basic concepts of the differential geometry of plane curves in complex representation and shows new and unified methods of construction for the circle of curvature and the affine normal. A general theory of plane motion in complex notation is outlined, using the angle of rotation of the moving system as

parameter. If z is the position vector of a general point of the moving system, then the nth derivative vectors $z^{(n)}$ for all such points, if placed at the points and rotated through $(2 - n)$ right angles, have common termini (poles) P_n. The resulting set of poles $P_1, P_2, \ldots P_n$ is used as the basis for a uniform and clear geometric treatment of plane motion and for methods of approximating the motion of a given system by that of another whose point paths coincide with those of the first to any desired order at the instant considered.

From author's summary by G. A. Nothmann, USA

4377. Stoppelli, F., On the principle of the gyroscopic effect (in Italian), *G. Mat. Battaglini* (4) **4** (80), 14–38, 1951.

Signorini has established the validity of certain simple approximations in the theory of the motion of a gyroscope [*Atti Accad. Naz. Lincei Mem. Cl. Sci. Fis. Mat. Nat.* (8) **1**, 1–41, 1946]. In the present paper, author investigates the extent to which similar approximations can be used in more general problems concerning a rigid body moving, with one point fixed, under the influence of external forces. Appropriate generalizations of Signorini's results are obtained, but they cannot be summarized easily in a way which is both concise and explicit.

Courtesy of Mathematical Reviews L. A. MacColl, USA

4378. Fogagnolo Massaglia, B., On the motion of an elastic sphere (in Italian), *Atti Accad. Sci. Torino* **84**, 1, 19–30, 1949–1950.

A method for solving dynamical problems in elasticity was given by Prof. R. Einaudi in 1939 [see *Ann. Matematica*, Ser. IV-T.XIX, pp. 1–33]. He gave also an example of his method for a sphere, when displacements and velocities are known in every point of the body for $t = 0$, and displacements on the surface are given for $t \geqslant 0$ [see title source, **74**, T.I, 1939]. Now author gives another example for the sphere: displacements and velocities in every point are known for $t = 0$, but, for $t \geqslant 0$ the stress (instead of the displacements) is given on the surface. Solution is obtained through series of spherical functions.

Giulio Supino, Italy

4379. Bundgaard, S., On the motion of a heavy particle on a smooth surface of revolution (in Danish), *Mat. Tidsskr.* B. 63–65, 1950.

Horizontal and vertical velocity components are computed, and some inequalities are derived. An investigation is made of the highest and lowest levels the particle reaches after a finite or infinite lapse of time. Stationary states are discussed.

Courtesy of Mathematical Reviews

J. A. Schouten, Netherlands

4380. Haacke, W., Remarks on the stabilization of a physical pendulum. I (in German), *Z. angew. Math. Mech.* **31**, 6, 161–169, June 1951.

Author investigates a physical pendulum for the positions about which stable oscillations are possible when the point of suspension performs a harmonic oscillation in the vertical direction. He concludes that for a rigid pendulum only the vertically downward and the vertically upward positions can be stable, depending upon the exciting frequency. In reviewer's opinion this result can be obtained from the stated particular solution of the linearized differential equation. Author shows that the introduction of a velocity-proportional damping modifies the results only quantitatively with regard to the stable frequency ranges.

Next, the case of an elastic mathematical pendulum (spring between mass and point of suspension) is considered. Author concludes from an approximate analysis that the pendulum with vibrating point of suspension may take an oblique stable position if the spring constant ρ is sufficiently large. Reviewer cannot agree with this conclusion since the analysis apparently does not hold for an infinitely large value of ρ, and no upper limit is given for the validity of the approximation. For a point of suspension at rest the oblique stable position is not acceptable.

A. I. van de Vooren, Holland

4381. Metelitsín, I. I., Concerning the oscillation of a wheel with an elastic tire (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **61**, 449–452, 1948.

4382. Tishin, M. M., The design of cam mechanisms with a rocking crank follower (in Russian), *Akad. Nauk SSSR Trudi Sem. Teorii Mash. Mekh.* **2**, 105–110, 1947.

Let A be the fixed point of a cam, C that of a straight-line follower, K the point of tangency, $\phi = \angle ACK$, $\psi = \angle CKA$. The follower will rock only if $d\psi/d\phi < \frac{1}{2}$. Then CK and the curvature at K are determined in terms of $\psi, d\psi/d\phi$, and $d^2\psi/d\phi^2$. The condition of convexity is stated in the same terms, and applied to the limiting case of a sliding follower.

A. W. Wundheiler, USA

Gyroscopics, Governors, Servos

(See also Rev. 4377)

4383. Macmillan, R. H., An introduction to the theory of control in mechanical engineering, New York, Cambridge Univ. Press, July 1951, xiv + 195 pp. $6.

Book is clearly and carefully written. It includes a presentation of the methods of analysis and design of automatic control systems developed in this country and presented in the better textbooks of electrical control. But these methods are applied here to mechanical and hydraulic components. By reason of this mixture, the book brings together the fields of mechanical and electrical engineering. It will be of greatest value to mechanical control engineers who find the present texts on automatic control too full of electrical circuits to suit their needs.

P. Le Corbeiller, USA

Vibrations, Balancing

(See also Revs. 4365, 4420, 4574)

4384. Zeuli, T., Generalization of Newcomb's method to study pseudoharmonic vibrations (in Italian), *Atti Accad. Sci. Torino* **84**, 1, 31–40, 1949–1950.

Paper gives a numerical method, based on series developments, for finding the natural frequency of free vibrations of a single-degree-of-freedom, nondamped vibratory system with a constant mass and a spring force which is a nonlinear function of the displacement. J. P. den Hartog, USA

4385. Crede, C. E., Vibration and shock isolation, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1951, xvii + 328 pp. $6.50.

An analysis of problems of particular interest to specialists in vibration and shock isolation has been accomplished admirably by this well-qualified author. The first two thirds of the publication is a theoretical treatment of problems involved in isolation and is presented as would be a well-written graduate school textbook. It lacks the detailed instructions, such as are included by Mindlin ["Dynamics of package cushioning," *Bell Sys. tech. J.* **24**, 353–461, July-Oct. 1945], by means of which engineers less

specialized in this subject can use more easily the results in their design problems. Book will be a valuable reference for qualified engineers who have more than an occasional minor skirmish with these problems.

In treating vibration isolation, consideration is given to isolation of forces which are generated within the equipment on isolators, and to isolation of the equipment from motions of its supporting structure. Single-degree-of-freedom systems are treated with and without damping and with a minor description of effects of nonlinear systems. Considerable attention is given to the vibration modes and methods of support of a rigid body (6 degrees of freedom). For shock isolation, separate consideration is given to shocks involving displacements greater than the maximum possible deflection of the isolator and to shocks involving less than this distance. The mechanical model generally used to illustrate shock isolation is a two-degree-of-freedom system consisting of a flexibly supported heavy mass on which, in turn, a light element is flexibly attached. By this method the dependence of the probability of damage on the natural frequencies of equipment under test as well as on the intensity and nature of the shock motion can be determined. The last third of the book is nonmathematical and deals with general properties of materials used for vibration isolators and with particular application for various types of equipment. Included in this section are train and truck installations and conditions peculiar to military applications. Irwin Vigness, USA

4386. Harrison, M., and Sykes, A. O., Wave effects in isolation mounts, *David W. Taylor Mod. Basin Rep.* 766, 44 pp., 41 figs., May 1951.

Both theoretical and experimental studies of wave effects in isolation mounts have been made. From the standpoint of vibration isolation, wave effects are important in the sense that the vibration-isolating properties of a mount are changed by their presence. The well-known "lumped parameter" theory of vibration mounts predicts that the vibration isolation of a mount increases at 12 db per octave for frequencies well above the resonant frequency of the spring-mass system. This theory holds true only when the wave length of the elastic wave in the mount is large compared to the dimensions of the mount. Standing waves occur, as would be expected, which in certain frequency ranges decrease the vibration-isolation properties of the mount by as much as 20 db. For practical mounts, wave effects are most detrimental in the most audible frequency range (500 to 1000 cps). The theoretical and experimental treatments are in good agreement, and indicate various methods for improving the vibration-isolation properties of the mount. Experimental data are presented concerning isolation mounts fabricated of various materials. From authors' summary by Henry G. Lew, USA

4387. Bellenot, Ch., and Lalive d'Epinay, J., Self-induced vibrations of turbomachine blades, *Brown Boveri Rev.* **37,** 10, 368–376, Oct. 1950.

Author presents experimental evidence with analytical justification of effectively single-degree, self-induced vibration of unconnected turbine blades in cascade. This basically two-degree system is found to have separate solutions, akin to single-degree flutter, for bending and torsion modes, the appearance of each mode being a function of velocity. Analysis eliminates coupled terms in equations of motion and defines separate critical velocities for bending and torsion, frequencies of which are close to naturals. This is satisfactory if the two frequencies are very dissimilar, being verified by tests. Aerodynamic forces are found substituting isolated blade for cascade, considering additional circulation around the blade induced by others in the configuration, and modifying the angle of attack to give comparable lift values. Theoretical and experimental values for critical velocity as function of angle of incidence show fair agreement. Technique of shrouding or wire interconnecting of blades (keeping blade pitch constant) successfully eliminated oscillations.

Stanley I. Weiss, USA

4388. Cahen, G., Study of bending and torsional vibrations by means of electromagnetic analogies. Application to frameworks of ships and aircraft (in French), *Bull. Assn. tech. marit. aéro.* no. 49, 459–473, 1950.

Decomposing a beam into a number of finite masses, joined together by elastic massless cantilevers, author describes a generalization of known electromechanical analogies by means of which it is possible to measure the eigenfrequencies of this system. To each mass corresponds an electrical network composed of two circuits, one analogous to shear force and displacement (due to bending and shearing), the other to bending moment and rotation. Frequency of electrical system has the inverted value of that of the mechanical one in order to realize the coupling of the two circuits. Extension is made to torsional vibration.

M. Kuipers, Holland

4389. Vietoris, L., On the use of the harmonic analyzer of Mader-Ott (in German), *Z. angew. Math. Mech.* **31,** 6, 179–181, June 1951.

Suggested use (1) shortens the course of driving style of the analyzer; (2) reduces to half the number of drivings round necessary for analysis of Fourier coefficients by Nyström's method; (3) obtains, by means of two additional drivings round and readings of the planimeter, the two coefficients a_1 and b_1 which were not approachable by Nyström's method till now.

W. Kochanowsky, Germany

4390. Wax, N., On amplitude bounds for certain relaxation oscillations, *J. appl. Phys.* **22,** 3, 278–281, Mar. 1951.

Amplitude bounds are obtained for the unique periodic solution of the generalized Lienard equation $\ddot{x} + f(x)\dot{x} + g(x) = 0$, when the functions $f(x)$ and $g(x)$ are restricted suitably. The restrictions are less severe for the lower than for the upper bounds. A class of equations is exhibited which includes the van der Pol equation and satisfies all the restrictions. Numerical results are given for the van der Pol equation.

From author's summary by J. W. Cohen, Holland

4391. Koval'skiĭ, B. S., Transverse oscillations of a weight being lowered (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **78,** 4, 645–647, June 1951.

Analytical solutions are presented for the pendulous oscillations of a mass being lowered on a hoist at constant velocity. The period and amplitude of oscillation are shown to be functions of the velocity, and the possibility of successively increasing amplitude is shown. A criterion is presented relating hoist velocity, initial displacement, and hoist length at which the amplitude of oscillation will start to decrease. Walter W. Soroka, USA

4392. Charles, H., On the wave equation in a hereditary field (in French), *Bull. Soc. roy. Sci. Liége* **20,** 3, 195–198, Mar. 1951.

The one-dimensional wave equation in a material having hereditary characteristics is:

$$U_{tt} - U_{xx} = {}_0\int^t k(t - \tau)U_{xx}(x, \tau)\, d\tau \qquad [1]$$

Using Laplace's transform, author gives a formal solution of [1] with the supplementary condition $\lim_{t\to 0} U(x, t) = 0$, $\lim_{t\to 0} U_t(x, t) =$

0; $\lim_{x\to 0} U(x, t) = A_0(t)$, $\lim_{x\to l} U(x, t) = 0$. Author gets explicit solution if $k(t) = \lambda^2 t$ or $k(t) = -\lambda \sin \lambda t$.

Dario Graffi, Italy

4393. Johnson, D. C., The application of admittance methods in the classical theory of small oscillations, *Engineering* **171,** 4453, 650–652, June 1951.

Author considers steady-state vibrations of mechanical systems whose components are mass points and linear springs. Admittance is defined as the ratio of the displacement amplitude at a specified mass point A to the force amplitude which is imposed at a specified mass point B; A and B may be identical. Admittances are studied as functions of the frequency ω of the imposed force.

Examples illustrate the calculation of the natural frequencies of systems, and of the changes in natural frequencies which result from adding new components to an existing system. Discussion features graphical constructions for combining admittances which are common to a given driving point, and the representation of admittances by ratios of polynomials in ω.

Reviewer's comments: Author mentions possible alternative treatment by use of electromechanical analogies, but is apparently unaware of the existing extensive development of this subject [Firestone, F. A., "The mobility method of computing the vibration of linear mechanical and acoustical systems," *J. appl. Phys.* **9**, p. 373, 1938; Olsen, H. F., "Dynamical analogies," D. Van Nostrand, 1943; Gehlshoj, B., "Electromechanical and electroacoustical analogies," Akademiet for de Tekniske Videnskaher og Dansk Ingeniorforening, Copenhagen, 1947]. Author seems also unaware that his results on polynomial representation and on the separation of the poles and zeros of an admittance can be taken over *in toto* from electrical communication engineering [Guillemin, E. A., "Communication networks," John Wiley & Sons, Inc., 1946].

Sanford P. Thompson, USA

Wave Motion, Impact

(See also Revs. 4385, 4392, 4520)

4394. Haskind, M. D., The pressure of waves on a barrier (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **4,** 2, 147–160, 1948.

Author considers the problem of the effect of a long plane barrier immersed a finite depth into infinitely deep water with harmonic surface waves. The problem is solved using the linearized theory of surface waves. Author obtains the amplitudes of the reflected and transmitted waves, the amplitudes of the force and moment on the barrier resulting from the waves, the phase shift in these quantities and, finally, the mean force and moment over a period. This problem was also considered at about the same time by F. Ursell [*Proc. Camb. phil. Soc.* **43,** 374–382, 1947]. Although the methods are different, results seem to be in substantial agreement where they overlap. Author concludes with a short discussion of the effect of finite length of the barrier.

J. V. Wehausen, USA

4395. Durand, H. P., and Rosenberg, R. M., A new approach to the design of metering pins in oleo struts, *Bull. Univ. Wash. Engng. Exp. Sta. Seattle* no. 118, *Aero. Ser.* no. 1, 61–71, 1951.

Paper presents method for design of oleo metering pins. Optimum performance is that making the integral of the square of vertical acceleration of piston motion with respect to the stroke a minimum. Using the calculus of variations, the displacement satisfying this optimum performance is expressed in terms of the time. The damping force (or metering-pin function) is then found from the equation of motion, and this force is then related to the metering-pin radius, enabling the pin radius to be expressed as a function of the pin length.

Good agreement is found with experiment except at the beginning of the oleo motion. Surface roughness leads to erratic behavior in the performance.

A. W. Babister, Scotland

Elasticity Theory

(See also Revs. 4378, 4406, 4415, 4433, 4446)

4396. Vallance, A., and Doughtie, V. L., Design of machine members, 3rd ed., New York, Toronto, London; McGraw-Hill Book Co., Inc., June 1951, x + 500 pp. $6.

This new third edition deserves mention because it is rewritten and brought up to date. It preserves its old character as a basic textbook for students and practicing engineers. An author seldom succeeds in improving an old edition without increasing its size, but it has been achieved by these authors. That a third edition of this book was necessary in so short a time is proof of the favorable reception it has received and of its value in the technical literature.

Wilhelm Ornstein, USA

4397. Szelagowski, F. F., Problem of plane elasticity in functions of complex variables (in Polish), *Arch. Mech. stos.* **3,** 1, 45–51, 1951.

The known formulas for the components of stresses and strains in the problem of plane elasticity, which can be expressed by means of two functions of complex variables, were given by Kolosov as early as 1909 ["Oh odnom prilozhenii teorii funktsiĭ kompleksnogo peremennogo k ploskoĭ zadache matematicheskoĭ teorii uprogosti," Yur'ev, 1909]. This theory was further developed in numerous papers by Kolosov and, above all, Muskhelishvili. Author deduces the said formulas by applying simple formal transformations to the biharmonic function formulated by Goursat.

J. Bonder, Poland

4398. Sag, N., Analytical investigation of certain types of machine frames cut from steel plate, and experimental verification of some of the results by photoelasticity, *Instn. mech. Engrs. appl Mech.* (*W.E.P.* no. 62), **163,** 311–316, 1951.

Analytical investigation is made of closed machine frames having two parallel members with constant cross section and curved, connecting the end members with variable cross sections. The center line of the end members is the arc of a semicircle. Members have constant thickness, and a symmetrical outward load is applied at the center of each of the curved ends. Effect of variation of width of end members on static and energy load capacity of the frames is investigated. Some of the results are checked by photoelastic analysis. In the straight sides the moment determined analytically agrees with the photoelastic determination within a limit of about 10%. The analytical determination of the load-carrying capacity is even closer when checked by the photoelastic method.

William B. Stiles, USA

4399. Aquaro, G., Theorem of mean value for equations of elasticity, *Riv. Mat. Univ. Parma* **1,** 419–424, 1950.

The author proves the following theorem of mean value. Let s_i be a vector satisfying Navier's statical equation throughout a sphere whose surface is Σ, whose center is at P_0, and whose radius is R, extraneous forces being zero. Let P be an interior point with coordinates x_i, let Q be a boundary point, and let the quantities G_{ij} be defined by

$$G_{ij} \equiv \hat{\delta}_{ij} + \frac{R^3(k-1)}{2(k+2)}\left[\frac{\partial^2}{\partial x_i \partial x_j}\,\frac{P_0Q^2 - P_0P^2}{PQ^3}\right]_{P=P_0}$$

while the definition of k in terms of the Lamé constants is $k = 2 + \lambda/\mu$. Then the value of s_i at P_0 is

$$s_i = \frac{1}{4\pi R^2}\oint_{\Sigma} G_{ij}s_j\,dS.$$

C. Truesdell, USA

4400. Corlett, E. C. B., Thermal expansion effects in composite ships, *Trans. Instn. nav. Archit. Lond.* 92, 4, 376–394, Oct. 1950.

Experiments were carried out to determine the form of the temperature-distribution curve through a vertical section of a ship. The tests were made with thermocouples buried in the shell and bulkheads of (a) a refrigerated passenger-cargo liner, (b) a passenger-cargo liner, and (c) a tanker. Author concludes that the effect of the paint was considerable and that a 60-deg gradient be considered standard.

A general theory for longitudinal and transverse stresses due to temperature as well as a system of computation for design-office use is developed.

The theory is checked by tests on models consisting of a steel hull and up to two aluminum-alloy decks. Heat was applied through resistance mats as the hull was supported on trestles in a water tank. Temperatures were measured with thermocouples and strains with SR-4 gages. Diagrams showing the distributions of temperature and stress are given.

Author concludes that, under certain climatic conditions, the compressive stresses in the decks of a composite aluminum-steel ship may be large enough to warrant consideration. Transverse stresses of an appreciable magnitude might exist.

Marshall Holt, USA

4401. Novozhilov, V. V., On the relation between stresses and deformations in a nonlinear elastic medium (in Russian), *Prikl. Mat. Mekh.* 15, 2, 183–194, Mar.-Apr. 1951.

Author's starting point is the fact that in case of small displacements, if there are conditions under which the strain-energy function exists, elastic properties of a homogeneous, isotropic, nonlinear, elastic body are characterized by three scalar functions of the invariants of deformation. These functions play the role of generalized elastic moduli, and while (like in the linear theory) more systems of moduli are possible, author has adopted a definite system with a clear physical meaning, as close as possible to the classic theory. Moduli: $K = \frac{1}{3}s_1/e_1$, ratio of the mean tension to the dilatation; $G = \frac{1}{2}(s_2/e_2)^{1/2}$, but for a constant factor, ratio of the intensity of the shearing stress to that of the shearing strain; $\omega = \xi - \psi$, a certain angle which characterizes the divergence from the similarity of deviators of stress and strain (namely, if μ and ν are Lode's parameters defining the shape of the deviators of stress and strain, respectively, then there is $\mu = 3^{1/2}\mathrm{tg}\xi$ and $\nu = 3^{1/2}\mathrm{tg}\psi$). The relations between stresses and components of strain and vice versa are expressed by these moduli and the differential conditions of compatibility between the functions K, G and ω necessary for the existence of the strain-energy function are given as well. Author points out that this theory can be applied under certain conditions to the problems of the theory of plasticity, which would mean enlarging the existing theories of plasticity which are all based on the supposition of similarity of deviators of stress and strain. Author mentions also that the obtained relation between the deviators of stress and strain has the form previously pointed out by W. Prager [*J. appl. Phys.* 16, 12, 1945], and that it could be effectuated without the condition of existence of the strain-energy function.

Dragoš Radenković, Yugoslavia

4402. Lubkin, J. L., The torsion of elastic spheres in contact, *J. appl. Mech.* 18, 2, 183–187, June 1951.

A small torsional couple is applied about the axis of symmetry of a system of two elastic spheres (or solids of revolution) which have been pressed together by a force perpendicular to their common tangent plane. This problem may be reduced to a "problem of the plane," and it has been found that in the absence of slip on the interface, the tangential traction is singular on the bounding circle. Hence, the assumption of no slip is physically untenable. In the solution given, allowance is made for slip by assuming that the tangential component of traction, for the area over which slip has progressed, is equal to the product of a constant friction coefficient and the normal or Hertzian distribution. A continuous expression for the traction is developed. A formula relating the radial depth of penetration of slip to the magnitude of the applied torque is given, and another relating this torque to the rotation of the contact surface of one of the bodies with respect to remote points within that body.

From author's summary by Wm. J. Carter, USA

4403. Montag, H., The infinite plate with a square hole loaded uniformly on the boundary (in German), *Ing.-Arch.* 19, 3, 155–161, 1951.

Author employs the generalized trigonometric functions $x = \cos(n)v$, $y = \sin(n)v$ of Grammel [*Ing.-Arch.* 16, 3/4, 1948] to solve a plane stress problem of an infinite plate having a square hole in it with external applied forces on the boundary of the hole. The parameter n is an integer satisfying $x^n + y^n = 1$, $(n > 2)$. Harmonic and biharmonic stress functions in the independent variables (ρ, v) where $x = \rho\cos(n)v$, $y = \rho\sin(n)v$ are constructed to satisfy $\nabla^4 F(\rho, v) = 0$. If on the boundary edge $\rho = \rho_0$ (constant) the applied forces are doubly symmetrical, only one-eighth of the plate need be considered. Appropriate boundary conditions must be invoked along the infinite edges. Author illustrates with the case $n = 8$ and chooses a suitable polynomial representation of the solution such that the boundary conditions are approximately satisfied when the constants are determined from a finite system of algebraic equations. A number of the stresses and stress trajectories are shown graphically.

D. L. Holl, USA

4404. Rivlin, R. S., and Thomas, A. G., Large elastic deformations of isotropic materials. VIII. Strain distribution around a hole in a sheet, *Phil. Trans. roy. Soc. Lond. Ser. A*, 243, 865, 289–298, Apr. 1951.

In continuation of Rivlin's program of obtaining significant exact solutions of the general equations of elasticity for strains of any magnitude and any form of strain energy in an incompressible body, authors consider an annular slab subject to uniform radial tension on its outer surface. In this case the solution is not exhibited, but a simple iterative procedure for calculation is presented. Very good agreement with experimental results over a wide range of deformations is obtained. C. Truesdell, USA

Experimental Stress Analysis

(See also Revs. 4398, 4421)

4405. O'Rourke, R. C., Three-dimensional photoelasticity, *J. appl. Phys.* 22, 7, 872–878, July 1951.

In problems of photoelasticity with regard to the electrodynamic light theory, the Fresnel tensor of the dielectric constant can be assumed to follow a linear invariant relation with the three-dimensional stress tensor, where photoelastic media generally can be considered as "weakly" anisotropic and inhomogeneous. To derive the suitable equations of geometric optics from Maxwell's

equations, author uses the classical method of Sommerfeld-Runge and obtains a special form of the Hamilton-Jakobi partial differential equation, from which he obtains solutions for axially and spherically symmetric cases. If the directions of the principal stresses rotate in the plane of the wave front, the theory shows that small rotations have no influence on the rotation of the integrated phase. H. Neuber, Germany

Rods, Beams, Shafts, Springs, Cables, etc.

(See also Revs. 4358, 4384, 4431, 4437)

4406. Beth, R. A., and Wells, C. P., Finite deflections of a cantilever strut, *J. appl. Phys.* **22,** 6, 742–746, June 1951.

Finite deflections of a cantilever strut are discussed with the help of a power-series solution of a nonlinear partial differential equation. The results so obtained are compared with those given by the standard solution in terms of elliptic functions. It is found that the two agree very well for values of the radius of curvature not exceeding one. The convergence of the power-series solution is not treated, thus seriously limiting its utility. The Euler-Bernoulli law of pure flexure is assumed, which should not be done for finite deflections [cf. B.R. Seth, Third Symposium Amer. math. Soc., "Elasticity," New York, McGraw-Hill Book Co., 1950, p. 64]. B. R. Seth, India

4407. Naylor, N., Non-prismatic continuous beams, *Civ. Engng. Lond.* **46,** 539, 540; 326–328, 436–439; May, June 1951.

Author considers adaptation of Hardy Cross method to nonprismatic continuous beams. Due to nonuniformity of beam cross section, some of the formulas (e.g., stiffness) will be nonsymmetric with respect to right or left. Gabriel Horvay, USA

4408. Kachanov, L. M., Stability of the plane form of deflection beyond the yield point (in Russian), *Prikl. Mat. Mekh.* **15,** 2, 195–206, Mar.-Apr. 1951.

Using von Mises' plasticity condition, author generalizes the Kirchhoff-Clebsch relationships and applies the energy method to the curved, the cantilever, and the simply supported beam. He concludes that the introduction of a von Kármán modulus in the elastoplastic range is not justified. George Herrmann, USA

Plates, Disks, Shells, Membranes

(See also Revs. 4403, 4422, 4423, 4424)

4409. Gerard, G., Note on bending of thick sandwich plates, *J. aero. Sci.* **18,** 6, 424–426, 432, June 1951.

Equations of equilibrium and compatibility are derived considering faces and core as three interconnected plates. Shear deformations of faces are disregarded and Poisson's ratio of core is taken as zero. This approach was carried further by A. van der Neut ["Die Stabilitaet geschichteter Platten," *Nat. Lucht-Lab. Amsterdam, Ber.* S.286, 1943] and by A. van Wijngaarden [AMR **1,** Rev. 1115]. N. J. Hoff, USA

4410. Reissner, E., and Stein, M., Torsion and transverse bending of cantilever plates, *Nat. adv. Comm. Aero. tech. Note* 2369, 39 pp., June 1951.

Paper presents a simplified method of determining deflections and stresses in cantilever plates under arbitrary loading conditions. The general partial differential equation of plate theory is replaced by two ordinary differential equations, by applying principle of minimum potential energy and assuming linear chordwise deflection (first two terms of a power series). Authors state that this assumption is most nearly valid for problems involving unswept plates under torque loading. For this reason most of the specific problems solved, involving static deflection, vibration, and buckling, are of this category. Results in certain simple cases are compared with elementary beam theory.

D. H. Winne, USA

4411. Conway, H. D., Axially symmetric plates with linearly varying thickness, *J. appl. Mech.* **18,** 2, 140–142, June 1951.

Author obtains the closed solution, for bending under symmetrical loading, of circular plates with thickness decreasing linearly from the center of the plate, in the special case when Poisson's ratio is 1/3. Since small variations of Poisson's ratio are negligible in effect, the results are applicable to most metals. In arriving at the solution, use is made of known solutions for rotating disks. On applying the method of variation of parameters, particular solutions are obtained for two special cases of lateral loading, and subsequent numerical examples compare maximum stresses with those of corresponding plates with constant thickness. Author's development for the special cases appears very favorable upon comparison with the approximate solution of a somewhat more general case by Favre and Chabloz [AMR **4,** Rev. 1072]. T. F. O'Brien, USA

4412. Gol'denveĭzer, A. L., Application of the solution of the Riemann-Hilbert problem to calculation of momentless shells (in Russian), *Prikl. Mat. Mekh.* **15,** 2, 149–166, Mar.-Apr. 1951.

Author shows that the momentless shell, as a whole, can be statically determined only by assuming certain boundary conditions. Author examines only the case where, for each extreme edge of the surface, there is given one statical and one geometrical condition. He assumes the supports of the shell to be made of a series of bars, by means of which each point of the edge is joined with a stable base. The position of a bar is described by an angle θ, a function of a parameter σ, which describes the position of given point. The problem is solved by using geographical coordinates. Author bases his work on that of Vlasov, Muskhelishvili, and his own. He arrives at an expression of a complex function of stresses and displacement in the surface and then applies the expression of Riemann-Hilbert. A particular case of a spherical shell is considered and the analogy made between the momentless surface and a strut system.

Witold Wierzbicki, Poland

4413. Vreede, F. A., Calculation of the membrane stresses in continuous stiffened cylindrical shells of arbitrary shape (in Dutch), *Ingenieur* **63,** 28, B.89–B.95, July 1951.

Paper is an extension of an earlier article of C. G. J. Vreedenburgh [AMR **4,** Rev. 2421]. The extended form of Clapeyron's theorem of three moments is shown to be applicable also to harmonic loads on noncircular shells. Furthermore, allowance is made for tangential displacements of the shells near the supports.

From author's summary by R. G. Boiten, Holland

4414. Kucharski, W., Contributions to the theory of a plate stressed in uniform shear, I, II (in German), *Ing.-Arch.* **18,** 6, 385–408, 1950.

Paper deals with theory of rectangular plate submitted to shearing stress at the boundary. Stress is constant or varying with time only; plate is supposed thin and, author believes, with small deflection. But reviewer remarks that equation studied by the author, $w_{tt} + \Delta\Delta w + \vartheta w_{xy} = 0$, is easily deduced with extension to dynamics of the statical equation derived by von Kármán for a plate with large deflection [see Timoshenko, "Theory of plates and shells," pp. 342–344]; otherwise, it is well

known that problems of elastic stability in plates can be considered only when large deflection is supposed. Nevertheless, author's studies on above equation are correct. As the condition for the stress shows that ϑ must be constant or dependent upon the time only, both cases are considered. In the first, putting $w = T_\rho(t)U_\rho(x, y)$, the equation $\Delta\Delta U_\rho + \vartheta U_{xy} = p(x, y)$ is obtained and studied; in the second case, a formal solution for periodical problems is given. Questions on stability of solutions are also explained. Author declares researches are an example of the perturbation calculations. Giulio Supino, Italy

4415. Schade, Th., New treatment of the Poisson and the inhomogeneous bipotential equation in rectangular domains with application to problems of torsion and bending of plates (in German), *Ing.-Arch.* **19**, 2, 118–127, 1951.

The harmonic and biharmonic equations are transformed with the help of the relations $x = \rho \cos^{2/n}\theta = \rho\, Cm\theta$, $y = \rho \sin^{2/n}\theta = \rho\, Sm\theta$, n being a positive integer. Solutions are obtained in the form $\phi = \rho^m F_m(\theta)$. An elementary description of the functions Sm, Cm, and ϕ is given. The ϕ-functions are used to get approximate solutions of the torsion and bending of simply supported and clamped square plate. Agreement with the Fourier series solution is quite good. The case of the plate bent by transverse pressure, which is an integral polynomial of the eighth degree in ρ, is discussed in detail and numerical results are obtained and tabulated.

Apparently the author is unaware of the work of A. C. Dixon [*Quart. J. Math.* **24**, 163–233, 1898] who first studied functions of the type Sm and Cm for $n = 3$. These functions have been used to obtain the exact solution of the torsion problem of an equilateral section [B. R. Seth, Lucknow University studies, no. XIII, 52–53, 1939]. It may also be pointed out that for values of n equal to 3 and 4, these functions reduce to elliptic functions.

B. R. Seth, India

4416. Gursahaney, H. J., and Martin, H. C., An observation regarding the deflections of uniform swept cantilevered plates, *Bull. Univ. Wash. Engng. Exp. Sta. Seattle* no. 118, *Aero. Ser.* no. 1, 100–107, 1951.

Considering the importance of deflections in the aeroelastic treatment of swept wings, authors have effected an experimental research to see whether the elementary beam theory can be extended to the case in question. An actual wing structure is replaced by a flat plate, and authors have tried plates with pure twisting and pure moment loading, concentrated load at tip, and uniformly distributed load. They have reached the conclusion that deflections may be calculated with good agreement by elementary beam theory, provided the plate be replaced by an equivalent beam located along an apparent elastic axis, the existence of which appears from experiment. For stress, authors compare the results by Sechler, Williams and Fung with those obtained by applying their simplified concepts and find acceptable agreement, except for a zone of perturbation in the neighborhood of the root. Arturo M. Guzmán, Argentina

4417. van der Eb, W. J., Computation of a plate clamped on three sides and free on the fourth (in Dutch), *Ingenieur* **62**, 26, 31–34, June 30, 1950.

The deformation of a rectangular plate clamped on three sides, free on the fourth one, and loaded uniformly normally to its plane is calculated approximately in two steps. The problem is solved by expanding the deflection into Fourier series for a plate, simply supported along two parallel sides, clamped on the third one, and free on the fourth one, first under uniform loading and next when loaded by arbitrary varying bending couples along the supported edges. These couples are again represented by means of a Fourier series. The coefficients of this series can be chosen in such a way that the slope along the simply supported edges vanishes in a number of points when the two solutions are superimposed. It is asserted that sufficiently accurate results are obtained by taking only three terms of the series into account, i.e., by satisfying the boundary condition of zero slope along the supported edges in three points only.

Graphs and tables are given of bending moments in some interesting points for a range of values of the ratio of the two sides and for two values of Poisson's ratio.

A. van Wijngaarden, Holland

4418. Schürch, H., Contribution to the statics of a beam of finite width (in German), *Z. angew. Math. Phys.* **2**, 1, 26–34, Jan. 1951.

Author considers a laminated plate of variable thickness consisting of a thin sheet, stiffeners, shear web, stiffeners, and thin sheet. He assumes that this thin sheet is capable of withstanding normal and shearing stresses in its plane, the stiffeners inclined to the x, y axes are capable only of resisting bending stresses, and shear web resists only in shear. Equilibrium considerations yield a fourth-order linear partial differential equation with variable coefficients relating load and deflection. This equation reduces to the ordinary biharmonic equation by making the proper modifications of the coefficients. A series expansion for the deflection in powers of y is assumed. The coefficients are functions of x. A physical interpretation is given for these coefficients.

From author's summary by Marvin Stippes, USA

4419. Schürch, H., Contribution to the statics of a beam of finite width (in German) *Z. angew. Math. Phys.* **2**, 2, 92–108, Mar. 1951.

This continues a previous article (see preceding review). Author suppresses bending in transverse direction and obtains a system of two ordinary differential equations for the deflection and angle of twist of transverse cross sections. New structurally significant values of the cross section are defined in addition to the well-known bending and torsion rigidity.

Two simple examples of rectangular plates, clamped at one edge subject to bending and torque, show the use of the formulas deduced. From author's summary by Marvin Stippes, USA

4420. Goran, L. A., A minimum energy solution and an electrical analogy for the stress distribution in stiffened shells, *J. aero. Sci.* **18**, 6, 407–416, June 1951.

Finite difference equations are derived for the internal forces in stiffened shell airplane structures by an elegant minimum energy analysis using Lagrangian multipliers. Solution of the equations is suggested by iteration or by electronic network analog. A numerical example is given. N. J. Hoff, USA

Buckling Problems

(See also Rev. 4431)

4421. Hopkins, H. G., and Brown, E. H., The effect of internal pressure on the initial buckling of thin-walled circular cylinders under torsion, *Aero. Res. Counc. Lond. Rep. Mem.* 2423, 13 pp., Jan. 1946, published 1951.

An extension of Donnell's work on torsional stability of cylindrical shells [*Nat. adv. Comm. Aero. Rep.* 479, 1933] is presented to cover the effect of internal pressure on the critical torsional stress. It is shown that Donnell's results are applicable with the

replacement of the stiffness parameter J by $J(1 + \phi/\beta^2)^{1/2}$ where ϕ/β^2 has the dimension of $(p/E)(d/t)^3$. Application to nacelle design is illustrated by one example showing a 70% increase in critical torsional stress for an internal pressure of 2 psi, and some 120% increase for an internal pressure of 5 psi. The edge conditions are found to be not important. Conrad C. Wan, USA

4422. Heald, W. R., Tests on the general instability of a stiffened metal cylinder under axial compression, *Coll. Aero. Cranfield Rep.* 45, 12 pp., Apr. 1951.

A thin stiffened metal cylinder liable to general instability was tested under axial compression and an investigation was made into possible methods of predicting the critical load from non-destructive tests. Particular attention was paid to the perturbation loading technique. The cylinder was finally tested to destruction and the actual failing load compared with the values given by various theories and empirical relationships.

It was not possible to predict the critical load from measurements of the normal restraint coefficient (or radial stiffness); the stiffness did not vary with end load according to any simple law, being sensitive to the amount of skin buckling and falling off very rapidly over the last small fraction of the load.

The possibility was indicated of finding the buckled wave form at failure from measurements of the cylinder distortion during comparatively light compression-load tests and/or radial perturbation loads.

Very good agreement was obtained between the failing load on test and the values predicted from Hoff's semi-empirical law and van der Neut's theoretical relationship, though in both cases the solution depended on some test information.

From author's summary by F. R. Shanley, USA

4423. Haringx, J. A., Instability of thin-walled cylinders subjected to internal pressure (in Dutch), *Ingenieur* 63, 29, 0.39–0.41, July 1951.

It is shown that under certain conditions a thin-walled cylinder may buckle when subjected to an internal pressure q (being relieved, however, from any axial loading). The proof given is quite elementary and leads to the critical value $q = \pi^2 Eah/l^2$ (a radius of cylinder, h thickness, l length). Reviewer is indebted to author for having detected an error in "Technische Dynamik" [by Biezeno and Grammel] which consists in neglecting a term in Eq. VII (30, 6 of that book) whereby it is impossible to derive Haringx' solution from the general equations given there. The required correction is duly discussed in the paper.

C. B. Biezeno, Holland

4424. Haringx, J. A., Instability of bellows subjected to internal pressure (in Dutch), *Ingenieur* 63, 29, 0.42–0.44, July 1951.

Like thin-walled cylinders (see preceding review), bellows may also become unstable when loaded by internal pressure. The critical value of this pressure, which is governed through Euler's well-known formula by the rigidity of the bellows with respect to bending, is computed only for rectangularly shaped corrugations. The result found has been checked experimentally.

From author's summary by C. B. Biezeno, Holland

4425. Martin, H. C., An instability problem arising in uniform cantilevered struts, *Bull. Univ. Wash. Engng. Exp. Sta. Seattle* no. 118, *Aero. Ser.* no. 1, 95–99, 1951.

The instability of a strut under combined bending and compression is considered. The thickness of the beam is considered very small compared to its depth, which is often the case with wind-tunnel model support struts. Solution for the first buckling load is obtained directly from the differential equation by the substitution of a suitable power series. G. V. R. Rao, USA

Joints and Joining Methods

(See also Rev. 4463)

4426. Wilder, A. B., Kennedy, W. B., and Crouch, F. W., Welding characteristics of open hearth and Bessemer seamless steel pipe, *Proc. Amer. Soc. Test. Mat.* 50, 763–780, 1950.

Authors investigated the mechanical behavior of deoxidized acid Bessemer steel for seamless steel pipes (C = 0.14; Mn = 0.45; P = 0.075), in comparison with a silicon-killed and a silicon-aluminum-killed open-hearth steel. Hardness surveys, macro- and microstructure, and magnaflux examination, tension, impact- and weld-bead flattening tests, were made. Results show the good behavior of the deoxidized acid Bessemer steel which met all the requirements of the ASME Boiler Construction Code for grade B steel pipe. W. Soete, Belgium

4427. Soete, W., and VanCrombrugge, R., Study of fatigue resistance of welded assemblies (in French), *Rev. Soud.* 7, 2, 90–97, 1951.

Some results for, and reflections on the fatigue strength of two types of symmetrical lap joints subjected to axial tension are given. The first type is a transverse fillet joint and the second a longitudinal fillet joint. The stress distribution is discussed. The static tensile strength and the location of rupture are measured and observed. The results are compared with experiences of other investigations. The urgent need for international uniformity in fatigue testing of welded joints is emphasized.

Ragnar Nilson, Sweden

Structures

(See also Revs. 4365, 4398, 4410, 4416, 4487, 4646, 4647, 4648)

4428. Klöppel, K., and Boué, P., Numerical examples in the theory of statically indeterminate structures (in German), *Bautechnik (Stahlbau)* 28 (20), 5, 6; 59–62, 72–76; May, June 1951.

These two papers concern a practical application of a general theory, rigorously developed in an earlier paper by Klöppel [AMR 4, Rev. 3849], which considers the effect of creep and shrinkage in the concrete portion of steel and concrete structures, thermal stresses, and movement of supports. Structure chosen for examples is a three-span highway bridge, in which the steel superstructure consists of two continuous girders on which a concrete slab is laid directly. Several simplifications of the general theory are found to be permissible in practical design if, for instance, the girder is deep in comparison with the thickness of the slab. Three methods of prestressing during erection to minimize tensile stresses in the concrete under traffic conditions are discussed, namely, preloading, displacement of supports, and combination of the two. Calculations for all examples are tabulated.

The series (including Klöppel's paper, op. cit.) appear to reviewer to constitute an unusually thorough study of both theoretical and practical considerations in the design and analysis of structures combining steel and concrete.

A. D. Topping, USA

4429. Pöschl, Th., On an application of matrix calculus to the theory of frames (in German), *Ing.-Arch.* 19, 1, 69–74, 1951

An expository article in which the equations for the deformations of the joints of a framework are put in matrix form.

A. Devinatz, USA

4430. Baldacci, R. F., Tests of a reinforced-concrete overpass (in Italian), *Atti Ist. Sci. Costr. Univ. Pisa Publ.* **18,** 24 pp., 1950.

The first portion of the bulletin describes a series of tests performed on an overpass on the highway between Florence and the sea. The structure is about 100 ft long and 20 ft wide, supported at each of three intermediate sections by a transverse beam supported by four columns. Longitudinal beams supporting the road surface were precast. A 12-ton load consisting of 7.2 tons on a 1.5-m diam, 2.2-m long roller and 4.8 tons on a 1.0-m diam, 1.1-m long roller was placed in several positions on the structure. Deflections of the slab were measured on a 1.25 by 0.90-m grid throughout the structure.

The second part of the bulletin includes a development of a deflection formula for a slab supported on two edges and free on two edges. The slab was assumed to be homogeneous and isotropic and to be subjected to a uniform load on a strip parallel to the unsupported edges. A solution is written for the plate equation for each of the three strips involved, and constants are evaluated by equating the deflections and their three derivatives along the boundaries of the strips.

The results of the analysis are applied to the structure tested, and when the slab stiffness D is evaluated from the test data, good agreement exists between the experimental and analytical influence values for deflection. Glenn Murphy, USA

4431. Niles, A. S., Formulas for bending with axial tension, *J. aero. Sci.* **18,** 5, 356–357, May 1951.

Note in Readers' Forum.

4432. Williams, D., The principles underlying the dynamic stressing of aeroplanes, *J. roy. aero. Soc.* **55,** 486, 362–381, June 1951.

Purpose of paper is to explain the principles governing the behavior of structures under transient dynamic loads, such as those encountered by aircraft structures during landing or flying in gusty weather. Paper is intended mainly for the young aeronautical engineer who may not be particularly well versed in this aspect of stress work. From author's summary

4433. Lin, T. C., and Yang, H. T., The St. Venant torsion problem for cross sections consisting of one loop of the hyperbolic limaçon, *Bull. Univ. Wash. Engng. Exp. Sta. Seattle* no. 118, *Aero. Ser.* no. 1, 112–119, 1951.

The polar equation of the loop of the hyperbolic limaçon considered (a special case of the hyperbolic or Pierey airfoil with the center of inversion lying at the conjugate focus of the hyperbola) is $r = l(\cos\theta - \cos\pi/2k)$ where $\theta \leq \pi/2k$, and l is constant. An exact solution is obtained for the tail angle equal to π/k where k is a positive integer. By adjusting the parameter k, a series of symmetrical airfoils of different fineness ratios can be obtained—from a thin strip to a full circle. Also obtained are such torsion functions as the displacement, the resultant shearing stress, and the torsional rigidity of the airfoil.

Frederick K. Teichmann, USA

4434. Sarkaria, G. S., Selection of a preliminary triangular section for gravity dams, *Civ. Engng. Lond.* **46,** 536, 99–101, Feb. 1951.

Systematic method is presented for determining a preliminary triangular section of a gravity dam from the following aspects: sliding on base, overturning, shear and compressive stresses. A special criterion that vertical stresses in upstream face be greater than external water pressure is also considered. Assumed uplift condition is maximum possible for uncracked section (triangular). Six graphs representing relationships between stability factors and variables and also a typical example are given. Method presented is valuable in preparing estimates of excavation and concrete quantities. Wm. R. Schriever, Canada

4435. Bosshard, E., Contributions to the theory and calculation of arch dams (in German), *Mitt. Inst. Baustat. ETH, Zurich,* no. 22, 164 pp., 1949.

Paper presents several developments and refinements in the analysis of arch dams by the well-known method of dividing the shell into horizontal (arch) strips and vertical (cantilever) strips. Deflections at points of intersection of strip center lines are investigated as due to elastic deformations of two systems under combined effects of external load and mutual forces between the two systems. Present method, as many others which preceded it, assumes radial mutual forces and postulates compliance of radial deflections only. Analytical details presented include a convenient procedure of solution of linear equations in the mutual forces between arches and cantilevers. Effects of temperature variations, of abutment deformations, and of varying wall thickness are investigated with thoroughness. Alternate method, which considers cantilever moments at various elevations as unknowns, is also presented with claim of increased accuracy of solution in case of narrow and deep canyon. Approximating assumptions are clearly stated; yet, in reviewer's opinion, it remains to be proved that their use does not reduce considerably the significance attributed to the refinements presented in this paper. Oscar Hoffman, USA

4436. Green, V. L., Passenger car frame analysis and strain gage tests, *Proc. Soc. exp. Stress Anal.* **8,** 2, 49–62, 1951.

After a calculation of the stress distribution in the frame due to a compressive force of 800,000 lb at the center line of draft, results were checked with the aid of wire-resistance strain gages on a full-scale compression test of the car. Generally, calculated stresses were higher than measured stresses. As a result of the test, some weak points of the structure could be strengthened.

R. G. Boiten, Holland

4437. Prentis, J. M., The distribution of concrete stress in reinforced and prestressed concrete beams when tested to destruction by a pure bending moment, *Mag. Concr. Res.* no. 5, 73–77, Jan. 1951.

A method is given for utilizing experimental data derived from bending tests on reinforced and prestressed concrete beams to determine the stress-strain relationship for concrete. No initial assumption is made as to the shape of this curve; the result obtained is unique for the given test data.

From author's summary by A. H. Finlay, USA

4438. Beer, H., Interaction between the metal beam and the reinforced concrete slab (in Spanish), *Cienc. y Técn.* **116,** 587, 187–220, May 1951.

Composite construction in which adequate shear connection is provided between the steel beam and the reinforced concrete slab is a well-established design in the field of highway bridges. Author presents the theory of such composite structures, derives formulas for computing bending moments and stresses under combined action of bending and direct stress, discusses the particular significance of the moduli ratio n and various shapes and effects of the shear connectors, especially with reference to previous studies, experiments, and publications by Dischinger, Saliger, Slack, Richart, Siess, Mörsch, Engineering Materials Lab. in Zurich, Maier-Leibnitz, Albrecht, and Fröhlich. It is regrettable that important applications, tests, and research work performed

with this type of structure in the United States have been overlooked [see, e.g., "Composite construction engineering handbook," North Arlington, N.J., Porete Manufacturing Company].

J. J. Polivka, USA

4439. Murashev, V. I., Resistance to cracking, rigidity and strength of reinforced concrete (Treshchinoustoĭchivost', zhestkost' i prochnost' zhelezobetona), Moscow, Izdat. Minist. Stroitel'stva Predpriyatiĭ Mashinostroyeniya, 1950, 269 pp.

Book appears to be the first comprehensive treatment of the subject. In chapter I, author states four fundamental problems inherent in reinforced concrete that require solution: (1) Determination of instant when cracks form; (2) determination of size of cracks after their appearance; (3) calculations measuring rigidity; (4) calculations of strength. Correct solutions of these problems depend on using actual stress state on cross section in following stages: (1) Before and at instant of cracking; (2) from appearance of cracks to formation of plastic hinge; (3) at moment of failure. Discussed next is stress-strain relation in concrete; theory of crack formation with supporting experimental evidence, stress strain in tensile reinforcement, equilibrium; strength and safety. Deformation in pure bending before and after cracking receives attention.

Chapter II is devoted to calculations of crack formation in members of rectangular and T- cross sections subjected to bending, eccentric compressive and eccentric tensile force. Influence of shrinkage on crack formation and definition of factor of safety based on cracking is given next. Finally, examples are given indicating use of graphs and derived formulas in estimating resisting moments at cracking.

In chapter III, formulas for strength and deformation (curvature) of members are derived with experimental confirmation. Moments of resistance based on limiting strength of concrete and length of cracks are estimated. Formulas for influence on deformation of shrinkage and moderate change in temperature are given as well as effect of creep between lapped steel. Considerable space is given to rigidity of beams and columns, followed by many fully worked-out examples illustrating use of formulas and graphs.

Last five chapters are reports of experimental work. Tests pertaining to formation and growth of cracks under a variety of conditions described in great detail are found in chapter IV. Experimental investigations of rigidity of reinforced-concrete elements are presented in chapter V; formation and growth of cracks in tension members axially loaded are covered in chapter VI; and methods of limiting the formation and growth of cracks are given in chapter VII. In final chapter, author states conclusions and suggests ten areas for future research.

Reviewer agrees with author that the more scientific theory will necessitate, on part of designers, better knowledge and understanding of properties and mechanics of concrete under stress. In reviewer's opinion, nonlinearity of stress strain, shrinkage, nonhomogeneity, plastic flow, and low tensile strength of concrete, especially plastic flow, greatly complicate development of a theory. Plastic flow is a function of mix, stress, and time. So, to estimate state of stress at a given moment, the history of loading must be known. Unless plastic flow effect is found to be small, it may be advisable to try and introduce it as a stress-time function.

S. Sergev, USA

4440. Roš, M., Technical material fundamentals and problems in reinforced concrete with regard to the future construction of structures in reinforced concrete [Die materialtechnischen Grundlagen und Probleme des Eisenbetons im Hinblick auf die Zukünftige Gestaltung der Stahlbeton-Bauweise] (in German), *Eidgenöss. MatPrüfAnst. Ber.* no. 162, xi + 314 pp., 1950.

This compendious report with more than 500 illustrations presents basic and original research work in reinforced concrete accomplished by author in Federal Materials Testing Laboratory and Research Institute in Zurich (EMPA) during his 25-year activity as director and president, and was published on the occasion of his retirement in September, 1949. Extensive research work pertains especially to bearing capacity and deformation of columns under compression and buckling, and to beams under simple and combined bending. Main purpose of these investigations was the static resistance against failure and also the fatigue strength, especially of concrete and reinforcing steel of high quality, determined on the basis of deformation diagrams in elastic, superelastic and plastic regions, under consideration of recent testing methods. For evaluation of safety factors, plastic deformation of concrete under compression, buckling, and bending was considered, always maintaining uniform conditions for determining and grading permissible stresses and safety factors, and emphasizing the economy of high-strength materials (cement and reinforcing steel) for special structures, such as long-span girder and arch bridges, rigid frames, thin shells, and folded slabs. The research is thoroughly discussed and illustrated in the following chapters: 1. Statical strength, fatigue, and deformation of concrete under compression, tension, and bending, and of reinforced concrete under compression; 2. Shrinkage and plastic flow of concrete; 3. Strength and deformation of various types of reinforcing steel (standard and high-tensile steel) under statical load and fatigue; 4. Bond; 5. Strength, deformation, and cracks of reinforced-concrete beams under statical and sustained load; 6. Trusses in reinforced concrete; 7. Buckling stability of reinforced concrete; 8. Prestressed concrete; 9 and 10. Allowable stresses—Theoretical and actual factor of safety; 11. Composite structures (steel and reinforced concrete); 12. Material-technical problems of the future development of reinforced-concrete structures—Conclusions. Research in prestressed concrete refers primarily to monolithic structures without anchorage, and measurements relating to shrinkage and plastic flow were carried on for nearly six years for the arch bridge over the Aare river.

J. J. Polivka, USA

4441. Vallette, R., Use of high elastic limit steel and regulation of constraints in structures (in French), *Ann. Inst. tech. Bât. Trav. publics (N.S.)* no. 199, 14 pp., July-Aug. 1951.

Full advantage of the use of high-tensile steel in reinforced-concrete structures can only be obtained by prestressing the reinforcement. In this way, excessive deflections and deleterious cracking, which would otherwise result from greater steel stresses, can be avoided and a greater economy of construction is achieved. Author describes this type of construction in relation to pylons, bridges, and bowstring girders. The girders consist of parabolic concrete beams, which take the reaction from the prestressing jacks and are thus put into compression by tensioning the ties. An economical design is thereby produced and the depth of the girder may be reduced to about $^1/_{20}$ of the span, as shown by some actual constructions which are described in detail.

G. G. Meyerhof, England

4442. Vasarhelyi, D., and Hechtman, R. A., Welded reinforcement of openings in structural steel members, *Weld. Res. Suppl.* **16**, 4, 182s–192s, Apr. 1951.

Tests are described of three types of arc-welded reinforcements for circular cutouts and square cutouts with various corner radii to determine efficiency for a plain-carbon structural steel under uniform tension. The cutouts were centrally located in a 36-in. wide tensile specimen with a 36-in. gage length.

Load-elongation plots for a 36-in. gage length are given for each specimen up to fracture, and strain concentrations at the

cutout are given for several specimens (it is not stated if strain readings are for elastic or inelastic stresses). The designs tested are evaluated on the basis of ultimate strength and energy absorption to failure. Reviewer remarks that the latter criterion appears to be of very limited significance since it is based on the average strain in a 36-in. gage length. George Gerard, USA

4443. Kerr, P., Restraints on the expansion of vertical tanks under liquid head, *J. Inst. Petrol.* **37,** 328, 209–223, Apr. 1951.

Formulas are developed for the correction, when necessary, of tank tables for the restraining effect on expansion exerted by the tank bottom and roof, by butt straps, and by horizontal and vertical seams. From author's summary

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 4428, 4467, 4475, 4476, 4497, 4672)

4444. Prager, W., and Hodge, Ph. G., Jr., Theory of perfectly plastic solids, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., Aug. 1951, x + 264 pp. $5.50.

Book is intended as an introduction to that branch of general plasticity theory known as the theory of perfectly plastic solids and is directed to the research worker as well as to the senior or graduate student majoring in engineering or applied mathematics.

Chapter headings include an introduction, basic concepts, trusses and beams, torsion of cylindrical or prismatic bars, plane strain, and extremum principles. Some results on limit analysis important to the relations between the theories of von Mises and Prandtl-Reuss are included.

Since the field discussed has been drastically limited, many important aspects of the general subject of plasticity have had to be omitted. For instance, time effects and anisotropy effects, so important in the applications of the familiar organic plastics, have been omitted. Authors have good reasons for restricting the field to be covered, but it then seems particularly advisable to devote more space to letting the reader know where the theory of the perfectly plastic solid applies and where it does not apply. Little is said to enable the student or engineer to decide whether or not the theory will apply in practice.

Although the mathematics has been kept simple and, in general, easy to follow, even the simplest mathematics becomes monotonous if not broken up by descriptive and explanatory material. Authors have done this to some extent, but most engineers would probably prefer more explanation of many of the mathematical equations by giving their significance and practical examples of their use.

Within its stated but limited field the book fulfills its purpose and is a welcome addition to the literature on plasticity, especially since much of the original work has been published in languages other than English. It should be of interest to those in the forming industries such as rolling, drawing, and extruding, as well as to those engineers concerned with determining the safety factors of various structures. L. E. Nielsen, USA

4445. Volkov, S. D., Generalized condition of plasticity (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **79,** 2, 213–216, July 1951.

Author modifies his earlier theory [AMR **4**, Rev. 2474] to explain discrepancy between observed yield stresses in uniaxial and in biaxial tension (or compression). To his previous expression for critical shear stress for slip, he now adds term proportional to hydrostatic component of stress. Desired inequalities are obtained, but no quantitative test of theory is attempted; nor is any direct evidence, from crystal data, offered in support of author's hypotheses. Willam Fuller Brown, Jr., USA

4446. Davidenkov, N. N., Markovets, M. P., and Timofeeva, M. N., On the nature of warping after plastic bending (in Russian), *Zh. tekh. Fiz.* **21,** 2, 178–186, Feb. 1951.

A rod, if bent (or straightened) plastically and then left free at high temperature, gradually unbends (or rebends) to some extent. Authors discuss two alternative interpretations of this behavior and an experimental method for deciding between them. Interpretation 1 attributes behavior to elastic aftereffect of individual fibers whose interactions are supposed negligible. Interpretation 2 supposes individual aftereffects small; it attributes behavior to interaction between those portions (A) of cross section where yield point has been exceeded, and those portions (B) where it has not. Since A by itself would have residual bend, whereas B would not, mutual constraints produce inhomogeneous state of macroscopic stress; creep or relaxation occurs at different rates in A and in B, because of their different plastic states; hence, over-all residual bend changes with time. Behavior in flexure should parallel that in tension according to interpretation 1, but not according to interpretation 2. Authors present data, at several temperatures, on flexure of aviation piston rings (with ends clamped in contact for several hours, then left free for several) and on tension of rods of similar material. In both cases, residual strain after 3 hr under load is from $^1/_{10}$ (at 300 C) to $^1/_4$ (at 400 C) of total strain under load; change after unloading is of this same order for flexure but only of order 10^{-2} for tension. Authors conclude that interpretation 2 is correct for materials tested. William Fuller Brown, Jr., USA

4447. Oding, I. A., Relation between criteria of the second regions of relaxation and of creep of austenite steel (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **75,** 2, 197–200, Nov. 1950.

Based on the equation, derived earlier, $V_R = -(\sigma - \sigma_R)/t_0$, where V_R is speed of stress decrease at relaxation, σ applied stress, σ_R limit stress of relaxation, and t_0 a constant, the relation is derived

$$V_p = (V_R/E)\exp(\sigma - \sigma_R)/b = (\sigma - \sigma_R)/t_0 E \exp(\sigma - \sigma_R)/b,$$

where V_p is creep speed. Experiments with heat-resistant steels corroborate qualitatively the validity of the derived equation. Author proposes carrying out a relaxation test in place of a creep test. George Masing, Germany

4448. Larson, H., and Klier, E. P., Strain hardening of mild steel in the torsion test as a function of temperature, *Trans. Amer. Soc. Metals* **43,** 1033–1050, 1951.

Object is to find relation between effective stress σ and effective strain δ (octahedral stress and strain different by arithmetical coefficient) for mild steel at low temperatures. Simple tensile strains are insufficient to calculate effective strain as brittle fracture occurs. Extensive ductility occurs under torsion so that these measurements are used to define effective stress to effective strain curve, fitting $\sigma = K\delta^n$ with strength coefficient K and strain-hardening exponent n. K increases and n decreases with temperature decrease.

Reviewer finds authors' acceptance of "total" plastic strain theory strange in view of recent experiments and analysis [Peters, Dow, Batdorf, AMR **3**, Rev. 2297; Morrison, Shepherd, *Instn. mech. Engrs.* **163**, p. 1, 1949; Prager, AMR **2**, Rev. 1003; Swainger, *Nature, Lond.* **165**, p. 360, 1950]. Total strain theory leads to unacceptable statement that plastic strain transfers with rotating stresses so that an initial elemental sphere is *always* an ellipsoid for *any* loading sequence. Reviewer showed [AMR **3**, Rev.

2214] that plastic stress-strain behavior should be described in *three*-dimensional space of octahedral stress, strain, plastic modulus. Simple tensile and torsion curves are quite distinct on this "octahedral-parametric surface." Reviewer feels authors' present evidence is important in indicating first stress-invariant influence on *rupture*, and suggests low-temperature structural members might be torsionally prestressed to bring them into ductile range of metal. K. H. Swainger, England

4449. Cahn, R. W., Slip and polygonization in aluminum, *J. Inst. Metals* **79,** part 3, 129–158, 1951.

Paper presents detailed and careful microscopic investigation of phenomena associated with deviations from ideal slip (cross slip, deformation bands) in aluminum. Crystals were made by a Chalmers method as plates $2 \times 20 \times 150$ mm, standard orientation being so that the glide plane and direction each formed an angle of 49° with the crystal axis. The same main glide system then operated up to 40% extension. Results: Cross slip takes place on several distinct planes, most commonly, however, on an octahedral one. Proportion of cross slip increases with increasing deformation and temperature. Deformation bands are formed at the boundaries of somewhat different elongated parts of crystal. They appear also in polycrystals and at elevated temperatures, but not in bend crystals. By annealing, progressive polygonization occurs within the bands; also new grains formed by recrystallization tend to advance along the bands. Polygonization is associated with local rumpling of free surfaces; it can be accelerated by applied stress. These results are discussed in terms of dislocation theory. They may explain the difference in stress-strain curves at tensile and pure shear tests, as investigated by Kochendörfer and Röhm.

Albert Kochendörfer, Germany

4450. Lodge, A. S., On the use of convected coordinate systems in the mechanics of continuous media, *Proc. Camb. phil. Soc.* **47,** part 3, 575–584, July 1951.

A coordinate system convected with the moving medium has been used by several authors and has some advantages. Author proves that the solution of the resulting equations is always possible in principle without referring the variables to a coordinate system fixed in space, though it may involve differential equations difficult to deal with. Method is illustrated by the solution of a problem of nonsteady motion involving an idealized incompressible homogeneous liquid having a rheological equation of state of a particular form. As the author states, the conditions of the problem would be difficult to achieve in an experiment.

W. M. Shepherd, England

4451. Oldroyd, J. G., Strawbridge, D. J., and Toms, B. A., A coaxial-cylinder elastoviscometer, *Proc. phys. Soc. Lond. Sec. B,* 64, part 1, 44–57, Jan. 1951.

An instrument is described which was designed to measure the elastic and viscous properties of liquids, primarily of solutions of linear high polymers whose elastic properties had already been observed qualitatively. The liquid is contained in a narrow annulus between two long vertical cylinders. The outer cylinder can be driven in steady rotation at a known speed, or in harmonic angular oscillations of known amplitude and frequency. In steady rotation, the torque on the stationary inner cylinder is measured at different speeds, and interpreted to give a viscosity coefficient as a function of shear stress. In oscillatory motion, the amplitude of oscillation of the inner cylinder, when constrained by a torsion wire, is measured and plotted against the frequency. The shape of the resulting graph can be interpreted so as to distinguish and measure different types of elastic behavior. The annular gap, the restoring constant of the torsion wire, and the amplitude of oscillation of the outer cylinder can be varied in discrete steps. The angular velocity of the outer cylinder can be varied continuously from 0.3 to 3000 rpm in steady rotation, and the frequency can be varied continuously from 0.25 to 25 cps in steady oscillation. The performance of the instrument in both steady-state and oscillatory experiments is assessed by comparing observed and predicted results for Newtonian liquids of known viscosity. An example is given of the behavior of a typical polymer solution in both kinds of experiment, together with a suggested quantitative interpretation of the results.

From authors' summary

4452. Fastov, N. S., On thermodynamics of plastic deformation (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **78,** 2, 251–254, May 1951.

For small strains, a linear relation between intensity of stress deviator and intensity of strain deviator is derived from free energy of a body plastically deformed with infinitesimal rate. That means a straight strain-hardening curve. At finite rate of plastic strain, free energy is determined by strain tensor and relaxation tensor, the latter characterizing deviation of system from equilibrium state [DAN 71, 875, 1950]. Obtained equations determine dependency of yield point and maximum elastic deformation upon strain rate and the dependency of stresses upon strain and strain rate at plastic deformation. Author states qualitative agreement of calculated creep curve with experimental data. Henrich Mussmann, Germany

4453. Mooney, M., Secondary stresses in viscoelastic flow, *J. Colloid Sci.* **6,** 2, 96–107, Apr. 1951.

Theoretical equations are developed for secondary stresses in a shearing viscoelastic fluid. The theory assumes that the elastic stresses developed by the continuous shear also relax continuously in accordance with Maxwell's relaxation theory of viscosity. The steady-state strains are analyzed by the theory of superelasticity. The final equations predict pressure effects to be expected in rotating viscometers of cylindrical, plate, and conical form. In the absence of thixotropy in the test liquid, the secondary stresses are quadratic in the angular velocity. Thixotropy leads to more complicated equations and permits agreement with more complex experimental results.

From author's summary by Paul M. Naghdi, USA

4454. Lévi, F., Effect of additional constraints, introduced after loading, in viscoelastic bodies (in French), *C. R. Acad. Sci. Paris* **232,** 20, 1809–1810, May 1951.

Author considers an arbitrary linear, homogeneous viscoelastic body subject to additional constraints after the loading has taken place. The variation of reaction X under these conditions becomes $X = X_0[1 - \exp(-E\epsilon_0)]$, where X_0 is the value of the reaction at the time of application of the loads, E is Young's modulus, and ϵ_0 describes the flow properties of the material as a function of time. Harry H. Hilton, USA

4455. Gifkins, R. C., The variation with strain-rate of the mechanism of deformation of a lead-thallium alloy, *J. Inst. Metals* **79,** part 4, 233–242, 1951.

Room-temperature creep tests at different loads caused strain rates differing by about 50,000 to one. At the smallest rate there was widening of the grain boundaries, indicating movement at the grain boundary, but no metallographic evidence of slip. The diffraction spots remained comparatively sharp, indicating but little distortion within the grain. At the largest rate there was heavy slip, little widening of the grain boundaries, and the diffrac-

tion spots were smeared out into a continuous ring. At intermediate rates there was a mixture of the two behaviors. Wood's cell mechanism was not observed. (Reviewer's note: The metallographic evidence was similar to that reported earlier in the *J. Inst. Metals* by Hanson and Wheeler in 1931, and by Jenkins and Mellor in 1935.) J. D. Lubahn, USA

4456. Boyer, R. F., Relation of tensile strength to brittle temperature in plasticized polymers, *J. appl. Phys.* **22,** 6, 723–729, June 1951.

Flory demonstrated that tensile strength of rubbery materials is related to the number average molecular weight: $T.S. = a - (b/M_n)$. This linear relationship has been found to hold true for other properties of plastics, and it was predicted that a linear relationship should exist between tensile strength and transition temperature for plasticized polymers, independent of the nature of the polymer. It is found that, whereas tensile strength vs. heat distortion follows this relationship for four different plasticizers in polystyrene, different straight lines are found for Vinylite VYNW when measurements are made of brittle temperature with different plasticizers. The hypothesis is advanced that diffusion rate of a plasticizer molecule is important in the fast brittle point tests. Existing data appear to corroborate the prediction that brittle temperatures should decrease linearly with plasticizer content and inversely as the activation energy for diffusion of the plasticizer molecule. Final conclusions are difficult to draw on the basis of available data.

Although this paper may appear to be somewhat removed from direct engineering applications, it contains information leading to a clearer insight into some of the factors that affect the engineering properties of plastics. A. G. H. Dietz, USA

Failure, Mechanics of Solid State

(See also Rev. 4472)

4457. Uzhik, G. V., Again on the resistance to fracture as a new criterion of toughness (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 11, 1716–1746, Nov. 1950.

A detailed polemical discussion on the critical remarks of Glikman, Davidenkov, Serensen, Friedman, Shaposhnikov, Shapov, and Yagn; no short review is possible.

George Masing, Germany

4458. Akulov, N. S., Mazin, I. P., and Fel'dshtein, Ya. I., On fatigue of metals (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **78,** 2, 263–266, May 1951.

Authors' model is as follows: In each stress cycle, microscopic cleavage cracks are formed at points where resistance to slip is high (and stress, therefore, concentrated); resulting redistribution of stress makes new points vulnerable on next cycle; process continues until total crack area reaches critical value; then cracks fuse, and failure occurs. By postulating various constancies and proportionalities (which to reviewer seem arbitrary), authors derive linear relation (with constants whose values are not deducible from the theory) between stress amplitude and logarithm of number of cycles till failure. Plots of data on six steels are consistent with such relation. William Fuller Brown, Jr., USA

4459. Jones, W. E., Jr., and Wilkes, G. B., Jr., Effect of various treatments on the fatigue strength of notched S-816 and Timken 16-25-6 alloys at elevated temperatures, *Proc. Amer. Soc. Test. Mat.* **50,** 744–760, 1950.

Authors present reversed bending-fatigue data on plain specimens and various notched specimens of S-816 (cobalt base alloy) and Timken 16-25-6 (a highly alloyed iron-base alloy), from room temperature to 1200 F. Conclusions are presented concerning treatments to reduce damaging effect of notches.

Alexander Yorgiadis, USA

Material Test Techniques

(See also Rev. 4442)

4460. Leslie, J. R., Pulse techniques applied to dynamic testing, *Proc. Amer. Soc. Test. Mat.* **50,** 1314–1323, 1950.

Author observes good correlation between soundness of concrete and group velocity of dilational waves in it. Rochelle-salt transmitter receives 800-volt pulse and emits damped wave train at natural frequency, here principally 20,000 cps. Time of transmission of waves (through as much as 50 ft of concrete dam) is measured by position of received wave train depicted on oscilloscope screen. Transmitter crystal is in oil-bath holder closed by elastomer diaphragm which makes good acoustical contact against moistened work. Equipment has been used in soundness determinations for dams, tanks, and sample bars of concrete; detection of heart rot in wood; and velocity in soil as affected by moisture and compaction. In concrete, velocities of 13,000 to 16,000 fps indicate sound material, while below 10,000 fps is suspect. Degree of cure can be followed by observing rise in velocity to final value. Vincent Salmon, USA

4461. Krautkrämer, H., and Krautkrämer, J., Practical material testing by means of ultrasonics (in German), *Z. Ver. dtsch. Ing.* **93,** 13, 349–362, May 1951.

This review of sonic testing methods for flaws in workpieces and welds emphasizes practical uses of the German equivalent of the Firestone-Sperry ultrasonic reflectoscope. There are many photographs which correlate the scope patterns with features of the cross section of the test piece. Treatment of shear wave patterns is especially interesting. Vincent Salmon, USA

4462. McSkimin, H. J., A method for determining the propagation constants of plastics at ultrasonic frequencies, *J. acoust. Soc. Amer.* **23,** 4, 429–434, July 1951.

In this method, in which a pulse technique is used, a thin wafer of the material under test is placed between two identical buffers of material having a known mechanical impedance (in this case fused silica); waves generated by quartz crystals at the ends of the assembly are transmitted simultaneously through the specimens in both directions. Comparison of transmitted and reflected components by means of a special balancing circuit provides information from which the complex propagation constant can be calculated, and hence dynamic elastic moduli and viscosities can be calculated. This method is particularly applicable to plastic materials in the frequency range of 5 to 50 mc; either transverse or longitudinal waves may be used. The expression which gives the ratio of the reflected to transmitted pressures is developed in the appendix and is used in the text. In the experimental apparatus a symmetrical structure is applied in order to send both reflected and transmitted waves in the same direction, which eliminates the difficulty encountered in the comparison. When the frequency is proper, these waves will be exactly out of phase and can be made to cancel if their relative amplitudes are adjusted to be equal. The general method can be applied to lower frequencies by using torsional waves instead of plane transverse waves. It can also be applied to liquid materials. Author gives some experimental data for polystyrene and nylon.

Salih Murat Uzdilek, Turkey

4463. Dietz, A. G. H., Closmann, P. J., Kavanagh, G. M., and Rossen, J. N., The measurement of dynamic modulus in adhesive joints at ultrasonic frequencies, *Proc. Amer. Soc. Test. Mat.* **50,** 1414–1426, 1950.

An adhesive layer between two cylindric metal rods is characterized by Nolle and Westervelt [*J. app. Phys.* **21,** no. 4, 1950] by a complex Young's modulus $E = E_1 - iE_2$. E may be measured without destruction of the specimen by a resonance method. Two equal steel bars are cemented end to end by the adhesive layer. This rod and a continuous bar of the same length and material are set electrostatically into longitudinal ultrasonic vibrations. The intensity of the vibrations is measured by a capacitor with one variable electrode. The frequency-measuring system consists of a crystal mixer to combine the output of the beat frequency and a stroboscopic frequency meter to measure the resulting sum or difference frequency. This acoustic technique is used to measure dynamic modulus of two stainless-steel rods cemented with a phenolformaldehyde polyvinyl-butyral adhesive with various heat treatments. Tensile strength is plotted against elastic modulus and against viscous modulus. Experiments show that measurements described make it possible to select deteriorated specimens and those of low tensile strength from those of large tensile strength. O. Ruediger, Germany

4464. Dahlquist, C. A., Hendricks, J. O., and Taylor, N. W., Elasticity of soft polymers. Constant-stress elongation tests, *Indust. Engng. Chem.* **43,** 6, 1404–1410, June 1951.

Authors apply method of evaluating elastic properties from elongation at constant stress developed by Taylor [*J. phys. Chem,* **47,** p. 235, 1943] to polymeric materials. The testing apparatus consists of bob of varying cross section such that, when the bob settles in fluid bath, stress remains constant due to elongation of a specimen. Reviewer finds elastic properties reported are of questionable value since computations were made on assumption that all deformation was elastic, as authors found it impossible to separate elastic and plastic contributions. In opinion of authors, plastic deformation is only several per cent of total.

Frank J. Mehringer, USA

Mechanical Properties of Specific Materials

(See also Revs. 4447, 4448, 4456, 4459, 4464)

4465. Frey, D. N., Freeman, J. W., and White, A. E., Fundamental effects of aging on creep properties of solution-treated low-carbon N-155 alloy, *Nat. adv. Comm. Aero. Rep.* 1001, 30 pp., 1950.

See AMR **3,** Rev. 2352.

4466. Marin, J., Pao, Y.-H., and Cuff, G., Creep properties of lucite and plexiglas for tension, compression, bending, and torsion, *Trans. Amer. Soc. mech. Engrs.* **73,** 5, 705–718, July 1951.

Reported creep tests at room temperature indicate greater creep in tension than compression—especially at high stresses. Computations of creep rates and deflections in bending based on creep data in tension and compression agree with observed values within 1 to 29%. Relationships employed were based on assumption that creep could be adequately represented by a linear function of time and a power function of stress. Reviewer believes that some important consequences of the theory which may seriously affect its utility and accuracy but were not mentioned in paper are: The predicted stress distribution and location of the neutral axis in bending are quite different between the time-independent and time-dependent terms, even though they must exist simultaneously at any given time; and the stress at a given location in the beam changes continuously during creep if the strain distribution is linear, whereas the strain-time equation employed in the derivation is considered to be applicable only for constant stress. William N. Findley, USA

4467. Marin, J., Faupel, J. H., and Hu, L. W., Combined tension-torsion creep-time relations for aluminum alloy 2S-O, *Proc. Amer. Soc. Test. Mat.* **50,** 1054–1070, 1950.

Results of 100-hr creep tests in combined tension and torsion on annealed aluminum tubes are presented. Test data are corrected for the increase in stress due to reduction in cross section. What appear to be small corrections in the creep curves make large changes in the constants of the stress-creep rate relation. Experimental results are compared with a modified Saint-Venant theory for predicting creep rates. Evan A. Davis, USA

4468. Frey, D. N., The general tensional relaxation properties of a bolting steel, *Trans. Amer. Soc. mech. Engrs.* **73,** 6, 755–760, Aug. 1951.

Author measures the tensional relaxation properties of a Cr-Mo-Si-Va commercial high-temperature bolting at 1000 F under varying conditions of follow-up by means of the step-down relaxation test. To this end he makes certain assumptions relative to high-temperature behavior. The validity of these assumptions was checked by means of a true relaxation test, with a particular value of elastic follow-up, carried out in a Barr and Badget test unit [*Trans. Instn. mech. Engrs.* **122,** 285–297, 1932].

From author's summary by Aris Phillips, USA

4469. Adams, C. H., The Izod impact test, *Amer. Soc. Test. Mat. Bull.* no. 173, 48–50, Apr. 1951.

Paper describes work done to find the effect of some well-recognized variables involved in the Izod impact method in tests on polystyrene, cellulosic and phenolic plastic materials. It is shown that the notch radius and depth for polystyrene should be accurately controlled, the former to closer limits than the tolerance permitted in ASTM method D256. The pressure exerted by the vise on the specimen is shown to exert no significant influence upon the impact test strengths of cellulosic and phenolic samples, but much upon the polystyrene. This leads author to suggest a standardization of vise grips. (It also suggests consideration of the Charpy type of mounting in which this clamping variable disappears.) Comment is also made on the variations experienced in tests on thin injection moldings which are not found with $\frac{1}{2}$-in. $\times$ $\frac{1}{2}$-in. bars. This is due to orientation in polystyrene giving increased toughness, a fact which is exploited in the correct design of molded articles. Author does not consider this point, but treats the test as one for material specification and, on this basis, rightly proposes the employment of the standard $\frac{1}{2}$-in. $\times$ $\frac{1}{2}$-in. specimen.

H. A. Nancarrow, England

4470. Grover, H. J., Bishop, S. M., and Jackson, L. R., Fatigue strengths of aircraft materials. Axial-load fatigue tests on notched sheet specimens of 24S-T3 and 75S-T6 aluminum alloys and of SAE 4130 steel with stress-concentration factors of 2.0 and 4.0, *Nat. adv. Comm. Aero. tech. Note* 2389, 64 pp., June 1951.

Report presents results of axial-load fatigue tests on notched specimens of three sheet materials: 24S-T3 and 75S-T6 aluminum alloys and normalized SAE 4130 steel. Notches included (1) stress-concentration factor 2.0: central circular hole, symmetrical edge notches, and fillets; (2) stress-concentration factor 4.0: symmetrical edge notches and fillets. For each type of

specimen, fatigue tests were run at several levels of nominal mean stress, including a zero nominal mean stress.

Fatigue strengths for these notched specimens are compared with values previously reported for unnotched specimens of the same sheet materials.

Axial-load fatigue-test results have been obtained on notched sheet specimens of 24S-T3 and 75S-T6 aluminum alloys and SAE 4130 steel. Several notch forms were used and tests were run at several levels of mean stress. The results show that: 1. Reduction in fatigue strength (in terms of nominal stresses) varies with (a) notch severity (theoretical stress-concentration factor), (b) notch form, especially for severe notches, (c) material, and (d) stress level—both nominal mean stress and nominal stress amplitude. 2. Simply defined fatigue-strength reduction factors do not appear to have useful correlation with the theoretical stress-concentration factor. From authors' summary

4471. Grover, H. J., Bishop, S. M., and Jackson, L. R., Fatigue strengths of aircraft materials. Axial-load fatigue tests on notched sheet specimens of 24S-T3 and 75S-T6 aluminum alloys and of SAE 4130 steel with stress-concentration factor of 5.0, *Nat. adv. Comm. Aero. tech. Note* 2390, 19 pp., June 1951.

Report presents results of axial-load fatigue tests on notched specimens of three sheet materials: 24S-T3 and 75S-T6 aluminum alloys, and normalized SAE 4130 steel. Each specimen was notched by edge notches designed to have a theoretical stress-concentration factor of 5.0. Tests were run at four levels of nominal mean stress: 0, 10,000, 20,000, and 30,000 psi. These tests extend information previously obtained on fatigue strengths of unnotched specimens and of specimens with less severe notches.

Comparison of results indicates increasing fatigue-strength reduction with increase in notch severity (as indicated by the theoretical stress-concentration factor). The increase in fatigue-strength reduction, however, is not in direct proportion to the increase in theoretical stress-concentration factor of the notch.

From authors' summary

4472. Yokobori, T., Fatigue fracture of steel, *J. phys. Soc. Japan*, **6**, 2, 81–86, Mar.-Apr. 1951.

Series of tests were carried out to determine distribution curves of fatigue strength for two types of steel at various stresses. Results are discussed and appear to agree with theoretical predictions. Relation between probability of fatigue fracture and thickness of fatigue layer is also discussed.

F. J. Plantema, Holland

4473. Marabais, L., and Nepper, M., Mechanical properties of Thomas steel with low nitrogen content (in French), *Ossature métallique* **16**, 6, 304–309, June 1951.

4474. Hardy, H. K., The ageing characteristics of binary aluminum-copper alloys, *J. Inst. Metals* **79**, part 5, 321–369, 1951.

Paper describes an extensive investigation into fundamental aspects of aging of aluminum alloys containing from 2 to 4½% copper. Specimens were chill-cast, forged, solution-treated at 520 C, and then quenched in water. Aging tests were run at temperatures from 30 to 240 C. Two types of aging curves were obtained. At the higher temperatures, single-stage aging, in which the hardness increased to a peak value and then decreased, was observed. At intermediate temperatures for certain alloys, an initial rise in hardness was followed by a period of constant hardness, after which the hardness rose to a peak value.

In all cases, the alloys with the greater amounts of copper had highest original and peak hardnesses. Where two-stage aging was observed, the time to reach peak hardness was almost independent of composition. Where single-stage aging was observed, the peak hardness occurred first in the alloys of highest copper content.

The aging is discussed in terms of the formation of certain zones of material known as G.P. 1 and G.P. 2. The G.P. 1 zones are platelike clusters of solute atoms. These zones are replaced by regions possessing an ordered arrangement of copper and aluminum atoms known as G.P. 2. These zones transform to the intermediate precipitate θ' which is the forerunner of the θ ($CuAl_2$) precipitate.

The initial rise in hardness is attributed to the formation of G.P. 1 zones. The single-stage aging at higher temperatures is associated with the formation of G.P. 2 zones directly from the matrix. The higher peak hardness reached with the two-stage aging is attributed to the simultaneous effect of G.P. 1 and G.P. 2.

Evan A. Davis, USA

4475. Laurent, P.-H., Particular aspects of gliding produced by alternating stresses in annealed aluminum (in French), *Rev. Métall.* **48**, 6, 441–446, June 1951.

Rolled, annealed, and etched aluminum strips are subjected to fatigue by alternate tension or bending. The grains develop slip bands in a great variety of designs. Special attention is called to certain patterns, exhibiting periodicity in two directions, showing either a parallelogram or a fishbone texture. None of the suggested explanations fits the experiments.

C. Zwikker, Holland

4476. Renouard, M., Stress-strain curves for light alloys (in French), *Rev. Métall.* **47**, 8, 614–618, Aug. 1950.

Several annealed light alloys are shown to conform to previous findings on other metals that the relation between the tensile elastic limit of deformed metal and the plastic deformation is independent of the type of deformation. Data obtained after deformation in tension, by rolling, and by wire-drawing are very closely represented by the expression $\sigma = A\delta^n - B$, where σ is the elastic limit in tension after a logarithmic strain δ ranging from 0.01 to 2.0, and A, B, and n are constants characteristic of the particular alloy. Alloys are identified only by European trade designations. John G. Leschen, USA

4477. Andersen, F., Studies on the mechanical properties of cellulose fibers in relation to the internal structure, *Trans. Dan. Acad. tech. Sci.* no. 3, 75 pp., 1950.

Paper reviews various theories of fiber structure and experiments relating it to mechanical behavior. Author attempts to do a more complete and fundamentally sound study of this relationship for cellulosic fibers than had been done prior to 1947.

Apparatus consists of a hand-operated micrometer screw for elongating the fiber, a load-measuring spring-suspended head, two condenser plates connected to the load head, and an electromagnet for producing longitudinal vibrations of various amplitudes and frequencies. The condenser plates are, in turn, connected to an electrostatic oscilloscope from which photographic records are made.

Author emphasizes the effect of temperature, relative humidity, and time effects on the resulting stress-strain relationships. These must be considered in relating fiber structure to mechanical behavior. Different parts of the fiber structure behave differently under the influence of these variables. Using the fringed micellar theory of molecular aggregate structure and the Tobolsky-Eyring reaction rate theory as an explanation of its deformation, he attempts to explain the behavior of the fiber as a whole under varying conditions.

He defines the static Young's modulus as the ratio between the stress and the strain where the stress is that obtained by relaxing the stress to a constant value at constant strain. When this is performed over the entire range of strains, it is the equivalent of obtaining a stress-strain diagram at an infinitely slow rate of strain. He then measures the effect of variations in relative humidity at constant temperature from 0% to 100% and soaked in water and the effect of variations in temperature from 20 to 140 C at 0% relative humidity.

A similar study was made of the dynamic Young's modulus at 25 and 40 cps by subjecting the fiber to damped longitudinal oscillations of very low amplitude while the fiber is under relaxed tension. This was performed under the same relative humidity and temperature conditions as for the static modulus.

Rate and degree of tension relaxation at fixed extension was similarly investigated as a function of relative humidity and temperature.

As a result of these experiments combined with previous investigations in the literature, author redefines the relationship between mechanical behavior and internal structure.

Reviewer believes author has developed a unique apparatus and a sound approach to those elements of fiber behavior which may best be used for correlation with internal structure. Reasoning is accurate and leads to significant conclusions. Paper suffers principally from lack of author's acquaintance with current literature, the most recent reference being in 1947. Much significant work has been published in the *J. applied Phys.* and *Text. Res. J.* since that time. Paper, however, is worthy of careful study by workers in this field. Rogers B. Finch, USA

4478. Birebent, A., Study of composition and properties of porous concrete (in French), *Ann. Inst. tech. Bât. Trav. publics (N.S.)* no. 165, 22 pp., Dec. 1950.

First part discusses experimentally determined effect of composition (fine and coarse aggregates, cement, water) on porosity. A wide range of values is covered systematically. Second part shows variations of tensile and compressive strengths, Young's modulus, and coefficient of thermal conductivity for certain of the concrete of the first part. M. P. White, USA

4479. Finch, R. B., Interfiber stress and its transmission. Part I: Measurement of the contact area between fibers under pressure, *Text. Res. J.* **21,** 6, 375–382, June 1951.

A method is described for revealing the contact area between a plane and a fiber under the action of a transverse pressure distribution. It involves pressing the fiber against a plane-glass surface which has been lightly smoked with a gas flame, and measuring the resultant impression microscopically.

From author's summary

4480. Dunell, B. A., and Dillon, J. H., The measurement of dynamic modulus and energy losses in single textile filaments subjected to forced longitudinal vibrations, *Text. Res. J.* **21,** 6, 393–403, June 1951.

Apparatus and techniques for measuring the dynamic properties of single fibers in the frequency range 1–100 cps at 70 F and 65% R.H. are described. For the viscose rayon, acetate rayon, nylon, feather keratin, silk, and polyethylene fibers studied, it is found that the quantities $\eta\omega$ and E are approximately independent of frequency in this range, where η is the internal friction, ω the radian frequency, and E the dynamic modulus. Measured values of the energy dissipated per cycle are found to be proportional to the square of the amplitude, in accordance with the prediction of the simple differential equation of vibration assumed (viscous damping and Hookean elastic reaction). Stress relaxation data were obtained with the same fibers and the results are given. Theoretical interpretation of the results is given in another paper. From authors' summary

4481. Germans, F. H., The abrasion test as a criterion to determine the wear of textiles, *J. Text. Inst. Trans.* **42,** 5, T185–T193, May 1951.

Author describes an apparatus for testing abrasion resistance of various materials. This consists of a long strip of emery paper wound between rollers which is drawn over the surface of the specimen. Loading on specimen and tangential force are measured. Abrasion is measured as loss in volume per sq cm per sec. It is found that with textiles the loss in weight is of same magnitude as that produced by changes in humidity, so specimens must be carefully dried for weighings before and after tests. Experiments were carried out on wool, glass, superpolyamide, "Perspex," and cow's hoof, presumably to show versatility of apparatus. Microscopic examination of wool fibers showed that nature of abrasion under test conditions is quite different from that found in actual wear. H. Kolsky, England

4482. Thorpe, T. C. G., Petroleum waxes: Their use and evaluation for paper packaging, *J. Inst. Petrol.* **37,** 330, 275–303, June 1951.

Paper reviews the usage, attempts to indicate the wax properties of greatest importance in packaging, and illustrates current practices in assessing these properties, in the hope that it will lead to closer co-operation between wax producers and wax users to the benefit of packaging. From author's summary

4483. Grube, K., and Eastwood, L. W., Magnesium-cerium cast alloys for elevated-temperature service, *Proc. Amer. Soc. Test. Mat.* **50,** 989–1010, 1950.

Paper constitutes progress report on program to develop alloys of higher strength-weight ratio for operating temperatures up to about 600 F, especially to replace Mg-Al-Zn alloys now used, which have poor creep resistance above 300 F. Study of about 350 heats of Mg-Ce cast alloys indicates that the best found so far is one containing 6% Ce, 0.8% Mn, 0.2% Ni, and 0.02% W in addition to Mg base. ("Cerium" is actually only 50% cerium; remainder consists of other rare earth metals.) At 600 F this alloy has following properties: tensile strength—13,900 psi; yield strength—7050 psi; elongation—36.3%; minimum creep rate (2500 psi)—0.0007% per hr; total deformation after 120 hr—0.12 to 0.14%. At room temperature: tensile and yield strength—17,850 psi; elongation—1%. Comparison with an Al-base alloy containing 4% Cu, 0.6% Fe, 0.8% Si, 1.5% Mg, 2% Ni, and 0.2% Ti shows that Mg-Ce alloy has only about half as much tensile and yield strength at room temperature, but nearly twice as much at 600 F, and greater ductility at all temperatures. Although prolonged exposure at 600 F causes Mg-Ce alloy to oxidize at surface, chemical treatment has been developed which greatly reduces oxidation. C. W. Smith, USA

4484. Grube, K., Davis, J. A., and Eastwood, L. W., Magnesium-cerium wrought alloys for elevated-temperature service, *Proc. Amer. Soc. Test. Mat.* **50,** 965–988, 1950.

This is the second paper in a series reporting results of a program to develop alloys of higher strength-weight ratio for operating temperatures up to 600 F, the first paper having dealt with Mg-Ce cast alloys [see preceding review]. Study of about 195 heats of Mg-Ce wrought alloys indicates that best so far found is one containing 2% Ce (including other rare-earth metals), 1 to 1.5% Mn, and 0.2% Ni. At 600 F this alloy has following properties: tensile strength—12,000 psi; yield strength—8200 psi; elongation—100%; creep rate (2500 psi)—0.001% per hr; total

deformation after 120 hr—0.205%. At room temperature: tensile strength—30,500 psi; yield strength—28,000 psi; elongation—4.0%. Comparison with two Al-base alloys shows that Mg-Ce alloy has only about half as much tensile and yield strength at room temperature, but more than twice as much at 600 F. Ductility of the Mg-Ce alloy is also less at room temperature, but greater at 600 F. As for most light alloys at 600 F, Mg-Ce wrought alloys show less resistance to creep than Mg-Ce cast alloys. C. W. Smith, USA

4485. Ziegler, N. A., and Brace, P. H., Hardening of austenitic stainless steels by mechanical working at sub-zero temperatures, *Proc. Amer. Soc. Test. Mat.* **50,** 861–879, 1950.

Austenitic steels of appropriate composition transform to ferrite (or martensite) during plastic deformation at room or lower temperature. Authors study such transformations in the range down to −300 F, and report progressively greater hardening with decreasing temperature of deformation. Heating at 700 F, after low-temperature deformation, results in further hardening. Authors also investigate the composition range in which the effect may be observed. George V. Smith, USA

4486. Rawson, H., A theory of stresses in glass butt seals, *Brit. J. appl. Phys.* **2,** 6, 151–156, June 1951.

A series of equations are derived which may be used for the calculation of the stresses in glass butt seals, including the case of a ring of one glass interposed between two tubular sections of another glass. These equations are of particular interest because they are developed directly from stress formulas familiar to many engineers. Photoelastic stress determinations made on actual seals show good agreement between calculated and experimental values. E. B. Shand, USA

4487. Thielsch, H., Strain aging of pressure-vessel steels, *Weld. Res. Suppl.* **16,** 6, 283s–290s, June 1951.

A clear condensed survey is given of the phenomenon of quench-aging and the mutually related phenomena of strain-aging and blue brittleness. The effects of the steel-making process, composition, heat-treatment, fabrication, and welding are considered. The importance of de-oxidation, low N-content, and normalizing is especially emphasized. In connection with suggestions for further study, it is pointed out that an unambiguous evaluation of the suitability of a steel for a structure on the basis of laboratory tests is still missing.

In the section on strain-aging criteria, author neglects to emphasize the essential difference between the degree of aging as derived from changes in hardness, yield point and tensile strength, i.e., quantities which are exclusively determined by the flow curve, and the degree of aging as derived from changes in elongation, reduction of area, impact value, transition temperature, etc., i.e., quantities which are determined by both the flow and the fracture curves. J. H. Palm, Holland

Mechanics of Forming and Cutting

4488. Schaub, C., Kinematics and kinetics of a frame saw (in Swedish), *Tekn. Tidskr.* **81,** 24, 517–520, June 1951.

Timber is fed horizontally at a constant speed against a straight saw blade fastened in a frame which is operated by a crank so as to perform a harmonic vertical up-and-down motion. The straight tooth-point line is set at a small angle to the vertical. The forward slope, in millimeters, of the tooth-point line referred to the length of stroke is termed *overcut*. If the overcut ratio, i.e., the ratio of the overcut to the feed of timber per cycle of crank radius, is used as a parameter α, the motion of the tooth-point line and the feed can be represented in a diagram in relation to the crank angle. Expressions are deduced for the thickness and the volume of sawings produced by a cutting tooth during the sawing interval. Results are discussed. The forces of reaction associated with the motion are composed of the feed pressure parallel to the direction of feed and the cutting force at right angles to this direction. The feed pressure reduces the feed of the saw. Therefore, author introduces the concept of feed efficiency. This efficiency was studied experimentally as a function of the tooth pitch at various values of α. The space available for sawings and the volume of sawings were also studied in the same manner as functions of the tooth pitch. The results are shown in diagrams without scales.

Finally, author reproduces results of photoelastic tests made by Hiltscher, at the Photoelastic Laboratory, Royal Institute of Technology, Sweden. Author's results are not to be regarded as a complete or exhaustive treatment of the problem. His purpose was to elucidate the general outlines of the subject.

S. T. A. Ödman, Sweden

Hydraulics; Cavitation; Transport

(See also Revs. 4395, 4669)

4489. Escande, L., Study of the stability of surge tanks with restricted inlet (in French), *Génie civ.* **78,** 12, 227–229, June 1951.

4490. Weirich, H., Analytical determination of the oscillation movement in the Johnson differential surge tank (in German), *Öst. Ing.-Arch.* **5,** 2, 154–173, 1951.

An approximate method is presented to calculate the oscillations in a Johnson differential surge tank. The method is based on a substitution of the effective movement by a damped oscillation, whose characteristics are determined by requiring that the differential system of the movement be satisfied at some particular moments; it allows determination of the extreme levels of water in the tank, the velocities in the gallery and the corresponding times, both for constant discharge and for constant power. Formulas from solution are rather complex; the attainable approximation seems to be good, except for some cases of closure.

Duilio Citrini, Italy

4491. Leclerc, A., Deviation of a liquid jet by means of a plate normal to the axis of the former. Determination of the free surface by electrical analogy (in French), *Rev. trim. Canad.* **37,** 146, 137–148, 1951.

See AMR 4, Rev. 2982.

4492. Jouenne, M., Surface tensions (in French), *Indust. Céram.* nos. 414, 415; 286–291, 329–333; Nov., Dec. 1950.

Papers summarize the basic laws of capillarity and the applications thereof to ceramics. Author discusses the measurements of surface tension of vitreous material and the effects of surface tension on vitrage, such as the brilliance of enamels, the beading of glazes, the formation of cavities, the shrinkage and the opacity of enamels. A few methods to modify the capillarity of enamels are cited. G. H. Keulegan, USA

4493. Erythropel, H., New measurements of the viscosity of steam (in German), *Brennstoff-Wärme-Kraft* **1,** 8, 215–218, Nov. 1949.

A brief review of earlier research on the determination of the viscosity of steam is presented. Comparisons are made of the experimental results of the various investigators. Author concludes by citing that, in view of the difficult problems involved,

it is not surprising that considerable deviations exist between the results of the several investigators, and that additional research is needed to clarify the existing disagreements. Author states that, until additional information is available, the results of Timroth may serve as a useful basis for calculations.

G. A. Hawkins, USA

4494. Deublein, O., Viscosity and thermal conductivity of steam (in German), *Brennstoff-Wärme-Kraft* **3**, 4, p. 123, Apr. 1951.

This is a very brief discussion of the viscosity and thermal conductivity values for steam. G. A. Hawkins, USA

4495. Richter, H., Probable values for the viscosity of steam (in German), *Brennstoff-Wärme-Kraft* **3**, 4, 117–120, Apr. 1951.

Author presents an extensive review of the existing experimental results dealing with the viscosity of steam, and discusses the existing differences. Due to the importance of steam-viscosity data in many engineering calculations, he feels that until new results are obtained, a set of probable viscosity values should be used. Article presents detailed information on the viscosity of steam at atmospheric pressure, viscosity of dry saturated steam at high pressures, viscosity at the critical state, viscosity of superheated and wet steam, viscosity-temperature diagram for steam, and kinematic viscosity. For those interested in this field, this article is recommended. G. A. Hawkins, USA

4496. Traustel, S., Thermal conductivity, viscosity, and thermodynamic properties of steam at high pressures and temperatures (in German), *Brennstoff-Wärme-Kraft* **3**, 4, 120–122, Apr. 1951.

This discussion presents a review of a Russian committee report on the thermal conductivity, viscosity, specific volume, and specific heat of steam. Under each main section the differences between the Russian and other existing experimental results are discussed. G. A. Hawkins, USA

4497. Melrose, J. C., and Lilienthal, W. B., Plastic flow properties of drilling fluids—measurement and application, *J. Petr. Technol. Trans.* **3 (192), 6**, 159–164, June 1951.

Use of Bingham's law in analysis of flow of drilling fluids is extended by application to their behavior in a rotational viscometer. The viscometric data may be expressed in terms of plastic viscosity (rigidity) and yield value. A commercially available rotational viscometer modified for multispeed work is suitable for use in the field as well as in the laboratory and gives results which are approximately relatable to Stormer measurements. The plastic flow properties of muds are shown to be functions of concentration and surface properties of the solids present, so that the susceptibility of a mud to chemical modifications may be predicted from plastic viscosity and yield-value data.

Stacey G. Ward, England

4498. Jaumotte, A., Viscosity of water and of water vapor (in French), *Rev. univ. Min.* (9) **7**, 213–225, July 1951.

A critical review of methods and results, including tables and graphs of best values. M. Reiner, Israel

4499. Bergeron, P., Similitude of wear caused by liquids carrying solids in suspension (in French), *Houille blanche* **5**, no. B, 716–728, Nov. 1950.

Author considers physical mechanism of wear as caused by (1) direct impact of jet on surface, (2) friction acting along surface, and sets up mathematical expressions to which each kind of wear is proportional. Only geometrically similar machines operating at dynamically similar operating conditions are considered. Analysis leads to two limits between which must lie the ratio of the rate of erosion in one machine to the rate of erosion in another (or inverse ratio of the times required for a given amount of erosion). Thus the rate of erosion in one machine can be predicted if known for the other. Some interesting relations for certain special conditions are also given. Approximations are involved in theory, and experimental correction factors are required. Author hopes to extend the theory to flat and curved stationary plates, since the theory can then be more easily checked experimentally. C. W. Smith, USA

4500. Jorissen, A. L., Discharge measurements by means of Venturi tubes, *Trans. Amer. Soc. mech. Engrs.* **73**, 4, 403–410, May 1951.

An attempt is made to present a comprehensive idea of the actual stage of development of the method of flow measurement by means of Venturi tubes. Use has been made here of (*a*) the latest available American and European standards, published by the various national associations; (*b*) decisions taken at the international meetings of the Committees on Flow Measurement; (*c*) published research reports. Both the nozzle-type and the Herschel-type Venturi are discussed from the viewpoints of discharge coefficient and pressure losses. Conclusions point to the need for further research and the necessity of international standardization.

From author's summary by Lawrence Talbot, USA

4501. Biésel, F., and Suquet, F., Laboratory wave generating apparatus (in French), *Houille blanche* **6**, 2, 147–165, Mar.-Apr. 1951.

Article, of which only the first part appears in reference cited, presents a comprehensive study, both experimental and theoretical, of the main types of wave-generating apparatus used in various hydraulic laboratories. The practical problems of motion and construction are defined. Then every type of apparatus is described: rigid or flexible flaps, plunger, cylinder, etc. A synoptic table classifies twenty different types according to their principle of operation. The first part of a theoretical study to determine the equations of motion is included. Irrotational motion of a perfect fluid is assumed. Author states clearly the advantages and limitations of such a theoretical study. Article is well illustrated with sketches and photographs.

André Leclerc, Canada

Incompressible Flow: Laminar; Viscous

(See also Revs. 4450, 4546, 4550, 4567, 4568, 4597)

4502. Kaufmann, W., On the mechanism of vortex cores of a Kármán vortex street (in German), *Ing.-Arch.* **19**, 3, 192–199, 1951.

The kinetic energy in the potential field of a vortex street with kernels of finite dimension is expressed in terms of circulation and stream function of the kernel boundary. Assuming elliptical circulation distribution along the radius of the kernel, the kinetic energy of the kernel is connected with its total circulation. Using the energy law, which gives a balance between the resistance of the two-dimensional body and the energy in the wake, and the von Kármán law for the circulation of the kernel and the transport velocity of the vortexes, author calculates the width of the vortex street and the diameter of the kernels. Application to the cylinder and the flat plate indicates that the theory is more useful for the cylinder than for the flat plate.

H. G. Loos, Holland

4503. Timman, R., The potential flow about a yawed ellipsoid at zero incidence, *Nat. LuchtLab. Amsterdam Rap.* F.74, 15 pp., 3 figs., 1951.

Formulas are presented to facilitate numerical calculation of surface-stream function of this well-known flow [cf. H. Lamb, "Hydrodynamics," Cambridge Univ. Press], and one numerical example is presented. Results are of interest in context of three-dimensional boundary-layer flow. A. Charnes, USA

4504. McNown, J. S., and Hsu, E.-Y., Approximation of axisymmetric body forms for specified pressure distributions, *J. appl. Phys.* **22**, 7, 864–868, July 1951.

Potential flow about axisymmetric bodies is treated by using elliptical coordinates. Developing the velocity potential in terms of Legendre polynomials, a simple relation between a given distribution of velocity and the profile form has been found. Assumptions to be made are a slender form of the body (thickness to length smaller than 0.3) and a neglected component of velocity normal to ellipsoidal coordinate surface. These assumptions are valid only in the intermediate portion, but no longer near nose and tail of the body. This fact is shown by some calculated examples. Authors mention that an analogous method has been given by A. D. Young and others in *Aero. Res. Counc. Lond. Rep. Mem.* nos. 2071, 2204; 1943, 1945. Fritz W. Riegels, Germany

4505. Babister, A. W., Marshall, W. S. D., Lilley, G. M., Sills, E. C., and Deards, S. R., The use of a potential flow tank for testing axisymmetric contraction shapes suitable for wind tunnels, *Coll. Aero. Cranfield Rep.* 46, 15 pp., 17 figs., Apr. 1951.

Author states report gives details of tests in the potential flow tank on a series of axisymmetric contraction shapes. Tests were in connection with the design of the 8-ft × 6-ft wind tunnel and a water tunnel. The potential flow tank provides a simple method of modifying an axisymmetric contraction shape to meet given requirements. Report shows that small modifications to a theoretical contraction shape for the 8-ft × 6-ft wind tunnel give a great reduction in total length with only a small adverse velocity gradient at the high-speed end of the contraction. Tests were concerned with contraction ratios of the order of 7:1, which is considerably larger than the contraction ratio of 4:1 tested by Cheers [Cheers, Raymer, and Fowler, *Aero. Res. Counc. Lond. Rep. Mem.* 2205]; thus the electrolyte at the high-speed end of the contraction was comparatively shallow, and special care was needed in manufacturing the model and in designing the electronic equipment. Details are given of the precautions taken in consequence. The over-all error of the apparatus is ±2% and suggestions are given for increasing this accuracy. Reviewer notes authors point out quite correctly that a monotonic wall-velocity increase is impossible with a finite length contraction, but say (p. 11) that in the final design there is "no (velocity) trough at the low-speed end." Apparently they mean no measurable trough.
Stanley Corrsin, USA

4506. Callan, M. M., The streamline pattern in the vicinity of a certain Joukowski aerofoil, with and without yaw, *Nat. Res. Counc. Canad. mech. Engng. Rep.* MA-240, 15 pp., Dec. 1950.

In part I, the calculation of streamlines in two-dimensional flow is considered. Results are presented graphically, both streamlines and plots of chordwise velocity component, for 0° and 6° incidence. The region covered extends about 1½ chords in front of the leading edge and the same distance behind the trailing edge, and somewhat more than half a chord above and below the chord plane. In part II, the effect of yaw is considered. An error in a previous paper by Watkins [*Nat. adv. Comm. Aero. tech. Note* 1231, 1947] is corrected. The procedure of numerical calculation is discussed. Graphical results are presented; the plan and elevation of streamlines near the airfoil are plotted for 0° and 6° incidence, for angles of yaw of 30° and 60°. Photographs are also shown of solid models of the stream surfaces.
W. R. Sears, USA

4507. Wintner, A., On a geometrical method of deriving three-dimensional harmonic flows from two-dimensional ones, *Quart. appl. Math.* **9**, 1, 102–105, Apr. 1951.

A result of Weingarten and Levi-Civita is stated in detail and with clarity, though without proof. Briefly, the method amounts to the following: In the Euclidean 3-space, select a surface S, introduce the Gaussian coordinates (u, v) on S, and construct an isotropic line congruence "radiating" from S. Along each line of the congruence assign the constant value $\varphi(u, v)$ to the function $\psi(x, y, z)$, where u and v are the Gaussian coordinates of the point at which the particular line intersects S. Then if φ is harmonic in u and v, ψ is so in (x, y, z) and represents a harmonic flow in three dimensions. The proof obviously depends on the isotropy of the selected line congruence, which is defined in paper. Usefulness of the functions thus constructed in solving boundary-value problems in potential flow is claimed by author, but has not been sufficiently demonstrated. Chia-Shun Yih, USA

4508. Trilling, L., The incompressible boundary layer with pressure gradient and suction, *J. aero. Sci.* **17**, 6, 335–342, June 1950.

Consider a laminar boundary layer in plane flow; let $u(x, y)$, $v(x, y)$, $p(x)$ denote the usual velocity components and pressure, all made dimensionless in the conventional manner. Crocco's transformation consists in introducing the new independent variables $\xi = x$ and $\eta = u(x, y)$; the shear $u_y = \varphi(\eta, \xi)$ then satisfies the equation $\eta\varphi_\xi - p'(\xi)\varphi_\eta = \varphi^2\varphi_{\eta\eta}$ with the boundary conditions $\varphi_\eta(0, \xi) - p'(\xi)/\varphi(0, \xi) = v_0(\xi)$ and $\varphi[u_1(\xi), \xi] = 0$, where $v_0(\xi)$ represents the flow through the porous wall and $u_1(\xi)$ the potential-flow speed related to $p(\xi)$, both presumed known. According to Carrier and Lin [AMR 1, Rev. 857], $\lim_{\xi\to 0}\varphi(0, \xi) = 0.332\,\xi^{-1/2}$. Author constructs a solution in the form $\varphi(\eta, \xi) = \sum_0^\infty \varphi_n(\xi)\eta^n$, actually using six terms in his numerical work, with the Carrier-Lin initial condition. After $\varphi(\eta, \xi)$ is known, the the profile, boundary-layer thickness, drag, etc., can be calculated with some labor. Finally, the stability of the layer can be investigated, using a criterion of Lin [*Quart. appl. Math.* **3**, 117–142, 218–234, 1945; **3**, 277–301, 1946]. As examples, the Blasius and Schlichting cases of zero pressure gradient, with and without suction, are treated. The method is then applied to the flow along the upper surface of an airfoil, under several conditions of suction. It is concluded that it is possible to maintain stability all the way to the trailing edge by proper use of suction.
W. R. Sears, USA

4509. Kawaguti, M., Numerical solution for the viscous flow past a sphere (in Japanese), *Rep. Inst. Sci. Technol. Tokyo* **4**, 5–6, 154–158, May-June 1950.

A numerical method of solving the Navier-Stokes equations for flow past a sphere is presented which is similar to Thom's method for a circular cylinder [Thom, A., *Proc. roy. Soc. Lond. Ser. A.* **141**, 658–669, 1933]. Actual calculation is carried out only for Reynolds number (based on the diameter) $R = Ud/\nu = 20$. Streamlines, equivorticity lines, as well as the vorticity and pressure distributions on the surface, are given. It is found that reversal of flow does not occur on the surface, so that standing vortex ring does not appear for $R = 20$. The drag coefficient is calculated as $C_D = D/(\frac{1}{2}\rho U^2 \cdot \frac{1}{4}\pi d^2) = 2.868$, in good agreement with existing experimental data. Isao Imai, Japan

4510. Golitzine, N., Method for measuring the size of water droplets in clouds, fogs, and sprays, *Nat. aero. Establ., Canada,* note 6, 13 pp. 22 figs., 1951.

Method consists of impinging water droplets on a $^1/_2 \times 12 \times {}^1/_8$-in. transparent plastic slide covered with a special oil along half its length. Droplets become embedded in the oil which retards their evaporation for sufficient period to permit photomicrographs to be taken of the slide samples. Descriptions and illustrations of photographic setup and sampling device are given. Samples are taken by manually swinging slide through droplet source in the case of fogs and sprays, and by exposing slide from an aircraft in cloud sampling. Effect of impact and exposure time in obtaining a representative droplet distribution is discussed. Droplets appear as nearly perfect spheres of various sizes in photographs. The diameters of a large number of spheres are determined by comparison with a standard, and a median diameter, defined as that diameter which divides the sample in two equal volumes, is obtained. Paper includes several photographs of fog, spray, and cloud samples illustrating size determination, effect of evaporation rate, concentration, and impact velocity.

Charles E. Carver, Jr., USA

4511. Loitsianskiĭ, L. G., Approximate method of integration of laminar boundary layer in incompressible fluid, *Nat. adv. Comm. Aero. tech. Memo.* 1293, 21 pp., July 1951.

See AMR **3**, Rev. 1545

Compressible Flow, Gas Dynamics

(See also Revs. 4542, 4543, 4545, 4551, 4613)

4512. Morikawa, G., Supersonic wing-body lift, *J. aero. Sci.* **18**, 4, 217–228, Apr. 1951.

Author considers supersonic wing-body interference for cylindrical bodies (extending to trailing edge of wing only) with (1) delta wings, (2) rectangular wings, and (3) delta wings with cut-off tips. Results for limiting cases are based on linearized theory and results for intermediate cases are obtained by semi-empirical analysis of theoretical calculations, some of them unpublished.

Reviewer wishes to point out that the corresponding subsonic problem has never been settled satisfactorily, either by theory or experiment. The greater importance of the subject in supersonic flow does not imply that it is any easier to find a conclusive answer. Exact results in (linearized) supersonic theory are obtainable more easily than in subsonic theory, but approximations are somewhat less reliable.

Paper under review may be regarded as a valuable contribution to a discussion (including papers by Ferrari, Spreiter, Ward, Lagerström, etc.) which may help eventually to produce a consistent picture of wing-body interference—and this is probably all that can be expected at the present stage.

A. Robinson, England

4513. Graham, E. W., The pressure on a slender body of nonuniform cross-sectional shape in axial supersonic flow, *J. aero. Sci.* **17**, 3, 173–175, 192, Mar. 1950.

The linearized theory for slender bodies is used to determine the pressure on an object that does not have rotational symmetry. The body extends infinitely far upstream as a circular cylinder, and in the region of interest (the distorted element) the cross section is gradually altered, without change of area, to a two-lobed shape at the downstream end of the element. The series of shapes passed through in the transition from circular to two-lobed is fixed. However, the rate at which this transition occurs (as a function of displacement in the downstream direction) may be varied.

The formula for pressure coefficient shows the dependency on rate of change of shape and also indicates that the pressure coefficient is proportional to the square of the thickness ratio of the distorted element. The thickness ratio of the distorted element is defined as the diameter of the initial circular cylinder divided by the length of the distorted element.

Since the expressions used for the perturbation velocities are independent of Mach number, the analysis applies to transonic and subsonic flows, as well as to the supersonic case. From this it can be shown that, within its limits of accuracy, the linearized theory for slender bodies predicts zero wave drag for distorted elements ending in cylinders. From Graham, E. W., "Pressure and drag on smooth slender bodies in linearized flow," *Douglas Aircr. Co. Rep.* no. SM-13417, Apr. 1949 [and probably from Ward, G. N., AMR **3**, Rev. 529] more general conclusions may be obtained to the effect that altering only the cross-sectional shape of a body of revolution (and not the area) does not change the drag if the body ends in a cylinder or a point. From Graham, op. cit., it can also be concluded that the dependency of pure shape-distortion pressures on thickness ratio squared is general.

The pressure coefficients are calculated for a particular example and appear to be of reasonable magnitude.

From author's summary

4514. Chang, C.-C., Transient aerodynamic behavior of an airfoil due to different arbitrary modes of nonstationary motions in a supersonic flow, *Nat. adv. Comm. Aero. tech. Note* 2333, 65 pp., Apr. 1951.

Report extends earlier work [AMR **2**, Rev. 221] and investigates transient motion due to (1) wing flapping, (2) vertical gust, (3) pitching, using Fourier integral methods. Results can be applied to transient effect of control surfaces. Using a convolution integral (see above reference), transient results can be applied to nonstationary harmonic oscillations if aerodynamic response to step-function disturbance is known. Applied to airfoil starting abruptly from rest. Results agree with Garrick and Rubinow [AMR **1**, Rev. 719] after transient effect of abrupt beginning has died out.

From author's summary by A. W. Babister, England

4515. Goldstein, A. W., Axisymmetric supersonic flow in rotating impellers, *Nat. adv. Comm. Aero. tech. Note* 2388, 36 pp., June 1951.

General equations are developed for isentropic, frictionless, axisymmetric compressible flow in rotating impellers with blade forces eliminated in favor of the blade-surface function. The characteristic equations for supersonic flow are developed and a computing technique is utilized to find the effect of variations of design parameters on internal flow and work-input distribution.

From author's summary by H. P. Liepman, USA

4516. Behrbohm, H., and Oswatitsch, K., Flat conical bodies in supersonic flow (in German), *Ing.-Arch.* **18**, 6, 370–377, 1950.

An unusually lucid and elegant development of the known theory, with novelty in reduction to a singular integral equation of the Prandtl "lifting line" type. This possibility was foreshadowed, perhaps, by the known reducibility of the wave equation for conical flow to the Laplace equation.

A. Charnes, USA

4517. Brown, W. F., The general consistency relations for shock waves, *J. Math. Phys.* 29, 4, 252–262, Jan. 1951.

For the case of uniform plane flow of an ideal gas before a shock, T. Y. Thomas in a series of papers [AMR: **1**, Rev. 147; **2**, Rev. 80; **3**, Rev. 318; **4**, Rev. 306] has derived general relations

connecting the curvature of the shock, the curvature of the streamlines behind it, and their derivatives. On these relations he had based a theory of the stability of shock waves. The paper under review extends these results, using the same methods, to the case where the flow preceding the shock is nonuniform and rotational. Included are generalizations of results on normal shocks attached to a solid boundary obtained with different methods by Lin and Rubinov [AMR 1, Rev. 139].

Courtesy of Mathematical Reviews D. Gilbarg, USA

4518. Shu, S. S., On two-dimensional flow after a curved stationary shock (with special reference to the problem of detached shock waves), *Nat. adv. Comm. Aero. tech. Note* 2364, 19 pp., May 1951.

Based on an assumed shock-wave shape, the problem of obtaining the two-dimensional flow pattern in a limited region downstream of the shock is formulated mathematically in terms of the stream function. Approximate analytic expressions are found for the stream function in the subsonic region following the shock, using certain simplifying assumptions including the neglect of vorticity. No numerical calculations are presented nor is any calculation procedure outlined in sufficient detail to make the method readily applicable. Lester L. Cronvich, USA

4519. Seeger, R. J., and Polachek, H., On shock-wave phenomena: waterlike substances, *J. appl. Phys.* **22,** 5, 640–654, May 1951.

See AMR **4,** Rev. 2107.

4520. Robinson, A., Wave reflection near a wall, *Proc. Camb. phil. Soc.* **47,** part 3 528–544, July 1951.

See AMR **4,** Rev. 1662.

4521. Oguchi, H., and Kawamura, R., On the shape of two-dimensional attached shock waves (in Japanese), *Rep. Inst. Sci. Technol. Tokyo* **4,** 9–10, 260–264, Sept.-Oct. 1950.

An approximate method is presented for determining the shapes of shock waves issuing from both ends of a two-dimensional slender body. Neglecting entropy variation, Mach lines are assumed to be straight. The equations which connect the coordinates (x, y) of the shock with (ξ, η) of a point on the body that lies on the same Mach line as (x, y) are written $dy/dx = \tan \mu_0 + \beta_1\theta + \beta_2\theta^2 + \ldots$, $y - \eta = (x - \xi)(\tan \mu_0 + \alpha_1\theta + \alpha_2\theta^2 + \ldots)$, where μ_0 is Mach angle of undisturbed flow, and θ is angle of inclination of the surface at (ξ, η). Coefficients β_i and α_i are functions of Mach number of undisturbed flow. From these equations the form of the shock can be determined. In particular, asymptotic behavior at large distance and curvature of the shock at the nose are dealt with. Finally, formula for the shape of bow shock of a circular-arc airfoil is given as an example.

Humio Tamaki, Japan

4522. Barry, F. W., Shapiro, A. H., and Neumann, E. P., The interaction of shock waves with boundary layers on a flat surface, *J. aero. Sci.* **18,** 4, 229–238, 270, Apr. 1951.

Experiments were performed at a fixed Mach number 2.05 but at four Reynolds numbers, 1.1×10^5, 2.5×10^5, 6.0×10^5 and 12×10^5, and six different incident shocks with deflection angles 1, 2, 3, 4, 5, and 6 degrees, respectively, in an 8-in. × 8-in. tunnel. For each case a schlieren photograph was taken. Surface pressure of the plate and constant density lines in the field were measured for the lowest three Reynolds numbers, and close agreement with previous investigations was obtained.

The dependence of flow on shock strength and Reynolds number was studied. Qualitatively, (1) with increasing shock-strength, the zone of interaction extends further both upstream and downstream, and the downstream boundary layer becomes thicker and highly turbulent; (2) with decreasing Reynolds number, the zone of interaction spreads out in both directions, having, however, not much effect in the reflected wave pattern, except at extremely high Reynolds number. From the photographs, the zone of interaction upstream and the boundary layer downstream were estimated as functions of the deflection angle. This shows that regularity breaks down at Reynolds number 1.2×10^6, which possibly indicates that boundary layer is already in transition. Finally, the interferograms provided seem to be rather instructive. Y. H. Kuo, USA

4523. Blackaby, J. R., An investigation of the effects of jet-outlet cut-off angle on thrust direction and body pitching moment, *Nat. adv. Comm. Aero. tech. Note* 2379, 39 pp., June 1951.

A wind-tunnel investigation was made to determine the effects of jet-outlet cut-off angle on the directional and spreading characteristics of an unheated, subsonic air jet, and on the pitching moment of the body from which the jet issued. The outlet was incorporated in the tail of an axially symmetric body and was cut at angles of 0°, 30°, 60°, and 75° relative to a plane normal to the outlet axis.

Force measurements show that the net effect of cutting the outlet as much as 75° from normal is only a slight change of the pitching moment of the body. This change is probably caused primarily by external loads on the outlets. In addition to the force measurements, visual studies were made of the flow in the jet exhausting from the outlets into still air. The characteristics of the flow in the jet observed in these studies are compared with characteristics shown by velocity profiles measured across air jets in other investigations. From author's summary

4524. Miles, J. W., A note on subsonic aerofoil theory, *Aero. Quart.* **2,** part I, 23–33, May 1950.

A linearized theory for the subsonic lifting surface is formulated in terms of Fourier integral solutions of Laplace's equation. The symmetric and antisymmetric problems of the first kind are solved explicitly, while the problems of the second kind depend on the solution of dual integral equations. The antisymmetric problem of the second kind is cast in a variational form, from which certain well-known theorems may be reduced.

From author's summary by A. E. Heins, USA

4525. Laitone, E. V., The surface pressure coefficient for approximate compressible flow solutions, *J. aero. Sci.* **17,** 6, 381–383, June 1950.

In the nth-order Rayleigh-Janzen method for calculating subsonic plane compressible flow, the velocity potential and speed of flow V are approximated by the first $n + 1$ terms of power series in the square of the free-stream Mach number, M_∞. Numerical computations indicate that the pressure coefficient C_p should also be approximated only to terms of the same order in M_∞^2 as V, rather than by the usual substitution of V in the exact equation for C_p. Contrariwise, it is asserted that in the first-order Prandtl-Glauert method for axisymmetric flow, too few terms of C_p are usually retained.

Courtesy of Mathematical Reviews J. H. Giese, USA

4526. Laitone, E. V., New compressibility correction for two-dimensional subsonic flow, *J. aero. Sci.* **18,** 5, p. 350, May 1951.

By using the local Mach number rather than the free-stream Mach number in the ordinary Prandtl-Glauert correction for subsonic two-dimensional isentropic gas flow, a simple new relation is obtained between the compressible and the incompressible

surface-pressure coefficient. The new relation includes the effect of the specific heat ratio and gives a better agreement with experimental data than does the von Kármán-Tsien relation.

From author's summary

4527. Cole, J. D., Drag of a finite wedge at high subsonic speeds, *J. Math. Phys.* **30,** 2, 79–93, July 1951.

An interesting analytical solution of the two-dimensional transonic-flow equation is presented. The pressure-drag coefficient of the front face of a finite wedge at zero incidence is evaluated. The calculated drag curve for Mach numbers slightly less than one is shown to be in reasonable agreement with measured values. Gerald E. Nitzberg, USA

4528. Truitt, R. W., Prediction of subsonic pressure distribution by the sound-space theory, *Engng. School Bull. N. Carolina State Coll.* no. 47, 16 pp., Sept. 1950.

Author derives a new expression for the relation between compressible and incompressible pressure coefficients. This relation is a result of the so-called sound-space theory, which author developed from the analogy of the special theory of relativity to the study of compressible fluid flow [AMR **3,** Rev. 2005]. With this method, pressure distributions on the airfoil NACA 4412 are calculated for different Mach numbers less than the critical. Result is compared with experiments and other theories. Author claims that agreement with experiments is considerably better for this theory than for other methods.

Tore Gullstrand, Sweden

4529. Bers, L., On the continuation of a potential gas flow across the sonic line, *Nat. adv. Comm. Aero. tech. Note* 2058, 58 pp., Apr. 1950.

Paper shows a number of sufficient conditions for analytic continuation across the sonic line of a two-dimensional transonic flow. If the velocity components and their first derivatives are continuous on the sonic line and if the velocity vector is neither parallel nor perpendicular to the sonic line, then there exists a unique solution in the neighborhood of the sonic line both in the physical and in the hodograph plane corresponding in one-to-one manner. No general statement concerning the extent of the supersonic region is made. A Cauchy problem is formulated in the hodograph plane by approximating the coefficient of the Chaplygin differential equation with a group of step functions.

C.-C. Chang, USA

4530. Vincenti, W. G., and Wagoner, C. B., Transonic flow past a wedge profile with detached bow wave—general analytical method and final calculated results, *Nat. adv. Comm. Aero. tech. Note* 2339, 47 pp., Apr. 1951.

Paper, first of three, outlines nonmathematically the theoretical analysis of symmetrical flow field with detached bow wave about double wedge profile. Aim of calculation is to make no special assumptions beyond those implicit in differential equation. Differential equation (Tricomi's) is that of hodograph method specialized to transonic small-perturbation limiting conditions and solved in subsonic zone over front half of profile by relaxation technique and in supersonic zone over rear half by transonic small-perturbation form of method of characteristics. Results of calculation include shape and location of bow wave and sonic line, chordwise Mach number and pressure distribution, pressure, drag, as functions of transonic similarity parameter. Lateral extent of subsonic zone was found large relative to longitudinal extent. Local Mach number M on profile was relatively constant as function of stream Mach number M_0 near $M_0 = 1$. In particular, condition of Guderley, Liepmann and Bryson, $(\partial M/\partial M_0)_{M_0=1} = 0$ was verified. This condition and rigorous supersonic theory provided criteria to help decide between various theoretical possibilities having same transonic small-perturbation limit, in practical application to specific airfoil. Other two papers of series will detail theoretical analysis and report on experimental investigation. William Perl, USA

4531. Teofilato, P., Application of the method of characteristics to supersonic vortical flow (in Italian), *Atti Accad. Naz. Lincei Rend. Cl. Sci. Fis. Mat. Nat.* (8), **10,** 2, 124–129, Feb. 1951.

Method of characteristics, usually applied for irrotational flow, is discussed for rotational steady two-dimensional flow. Using three characteristic relations for the three unknown functions ψ_x, ψ_y, S, (ψ stream function, S entropy), author develops a step-by-step construction, similar to well-known constructions of other authors; see, e.g., § 20 of reviewer's book, "Theor. Gasdynamik," 2nd edition, Berlin, 1951. Finally, author gives an estimation of errors. Robert Sauer, Germany

4532. Woersching, T. B., Negative camber airfoils for transonic flight, *J. aero. Sci.* **18,** 6 361–368 June 1951.

Experimental data indicate that critical Mach number can be increased and diving moments avoided at transonic speeds by using "W" cambered airfoils. Keith C. Harder, USA

4533. Cherry, T. M., Relation between Bergman's and Chaplygin's methods of solving the hodograph equation, *Quart. appl. Math.* **9,** 1, 92–94, Apr. 1951.

Using his partial fraction expansion of the hypergeometric functions $\psi_\nu(\tau)$, author shows that, with polar coordinates $(\tau^{1/2}, \theta)$ in the hodograph plane, the general Chaplygin solution $\psi = \sum_\nu c_\nu \psi_\nu(\tau) e^{i\nu\theta}$ for the compressible flow stream function ψ can be converted to Bergman's form:

$$\psi = V(\tau)\{\phi_0(\zeta) + {}_0\int^\zeta \sum_1^\infty (\zeta - t)^{n-1} p_n(\tau)\phi_0(t)dt/(n-1)!\},$$

where $$\phi_0(\tau) = \sum_\nu c_\nu \delta^\nu e^{\nu\zeta}, \zeta = \lambda + i\theta$$

and $V(\tau)$, λ and $p_n(\tau)$ are determinate functions of τ. Chaplygin's form is valid for all θ but requires $\phi_0(\zeta)$ to be regular in the whole of a strip $\zeta_1 < \mathrm{Re}\ \zeta < 0$; Bergman's form restricts θ to a sector $-3^{1/2}|\lambda| < \theta < 3^{1/2}|\lambda|$ of this domain but requires only bounded analytic behavior of ϕ_0 in this region.

A. F. Pillow, Australia

4534. Higgins, R. W., and Pappas, C. C., An experimental investigation of the effect of surface heating on boundary-layer transition on a flat plate in supersonic flow, *Nat. adv. Comm. Aero. tech. Note* 2351, 29 pp., Apr. 1951.

Wind-tunnel tests have been performed at a nominal Mach number of 2.4 in a range of $T_w/T_\infty = 2$ to 2.8, where T_w is absolute wall temperature, T_∞ free-stream temperature. The transition Reynolds number based on the length of run from the plate leading edge, displacement or momentum thickness with fluid properties defined alternatively at the free-stream and wall temperatures, all indicate that an increase in surface temperature decreases the Reynolds number of transition. The average skin friction in the laminar layer is found to be about 35% higher than the theoretical values. In reviewer's opinion, this might be due to the disturbing effects of the boundary layers on the side walls which made the flow slightly converging [cf. W. Tillmann: "On the skin friction of turbulent boundary layers with increasing pressure," Göttingen, Diplomarbeit Univ., 1947]. On the other hand, a rough estimate for incompressible flow with constant free-stream velocity gives for the correction over the average skin

friction: displacement thickness over breadth of tunnel, which is too small a value to bridge the gap between the tests and the two-dimensional theory. Karl Wieghardt, England

4535. Stine, H. A., The flat plate laminar boundary layer in a steady accelerated compressible fluid, *Bull. Univ. Wash. Engng. Exp. Sta.* no. 118, *aero. Sec.* no. 1, 12–25, 1951.

Set of differential equations obtained by Emmons and Brainerd [*J. appl. Mech.*, A1–A6, 1942] are extended to include case of pressure varying as power of distance from leading edge. When pressure varies as reciprocal of square root of this distance, set of equations may be integrated by quadratures in case of insulated plate. Approximate solution is found for case when heat-transfer rate at plate is given. These solutions are utilized to study boundary-layer growth in wind-tunnel nozzles.

John A. Lewis, USA

4536. Penner, S. S., Thermodynamics and chemical kinetics of one-dimensional nonviscous flow through a Laval nozzle, *J. chem. Phys.* **19,** 7, 877–881, July 1951.

Explicit relations are obtained for the enthalpy changes in one-dimensional nonviscous flow through a Laval nozzle, where arbitrary deviations from thermodynamic equilibrium of chemical composition of internal electronic, vibrational, or rotational energy states may occur. Starting with the equation of continuity for a multicomponent mixture of reacting gases, criteria are derived for near-equilibrium and for near-frozen flow with respect to chemical reactions. The near-equilibrium criteria agree with results obtained previously. The near-frozen flow criteria are new and have not yet been applied to the study of chemical relations during nozzle flow.

From author's summary by M. J. Goglia, USA

4537. Howarth, L., Some aspects of Rayleigh's problem for a compressible fluid, *Quart. J. Mech. appl. Math.* **4,** part 2, 157–169, June 1951.

The flow caused by an infinite thermally insulated plane that suddenly starts from rest and then moves with a constant velocity in the direction parallel to itself in a gas is investigated. Author obtains an approximate solution for the pressure-time variation at the plane when the Mach number is small and the Prandtl number is $^3/_4$, and a solution for the initial motion by use of the complete equations of motion with a constant coefficient of viscosity. The pressure at the plane rises instantly and then falls to half its initial value in about 5×10^{-10} sec and to one tenth its initial value in about 10^{-8} sec. Because of relaxation-time effects, however, the results are believed to require modification up to times of the order of 10^{-4} sec. For times greater than 10^{-4} sec, the excess pressures are negligible. It is inferred that the start of the motion is accompanied by rapid pressure changes that disappear in the order of 10^{-4} sec.

Neal Tetervin, USA

4538. Vallander, S. V., Equations of motion of viscous gas (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **78,** 1, 25–27, May 1951.

Author states that if the changes in hydrodynamic parameters over a characteristic length L are of the same order of magnitude as the parameters themselves, the equations of motion should contain additional terms to account for density and temperature, self-diffusion and density heat conduction, and become: $d\rho/dt + \rho \operatorname{div} \vec{V} = \operatorname{div} \vec{Q}$; $\rho(d\vec{V}/dt - \vec{F}) + \vec{V} \operatorname{div} \vec{Q} = \operatorname{div} \tau$; $\rho dE/dt + (E - V^2/2) \operatorname{div} \vec{Q} = \operatorname{div} \vec{t} + (\tau \cdot \operatorname{grad}) \cdot \vec{V}$; where $\vec{Q} + \mu[\alpha_1 \operatorname{grad} \log \rho + \alpha_2 \operatorname{grad} \log T]$, $\vec{t} = \mu c_v [(\tau/\rho)\beta_1 \operatorname{grad} \rho + \beta_2 \operatorname{grad} T]$ and other parameters have their conventional meanings. α_1, α_2, β_1, β_2 are numerical constants of order unity. Leon Trilling, USA

4539. Rossow, V. J., Applicability of the hypersonic similarity rule to pressure distributions which include the effects of rotation for bodies of revolution at zero angle of attack, *Nat. adv. Comm. Aero. tech. Note* 2399, 28 pp., June 1951.

The error introduced into pressure distributions and drag of ogive cylinders by ignoring the rotation term in the characteristic equations is investigated. It is found that the influence of the rotation term on pressure distribution and drag depends only upon the similarity parameter K (Mach number divided by fineness ratio). Although the error in drag, due to neglect of the rotation term, is negligible at $K = 0.5$, the error is about 30% at $K = 2.0$.

Charts are presented for the rapid determination of pressure distributions for rotational flow over ogive cylinders for all values of the similarity parameter between 0.5 and 2.0 within given defined limits of Mach number and fineness ratio.

From author's summary by R. C. Prim, USA

4540. Van Dyke, M. D., The combined supersonic-hypersonic similarity rule, *J. aero. Sci.* **18,** 7, 499–500, July 1951.

Shows that the supersonic similarity rule $C_p = \tau^2 P[\tau(M^2 - 1)^{1/2}]$, where τ is a thickness parameter, is a valid hypersonic approximation. W. J. Strang, England

4541. Sauer, F. M., Convective heat transfer from spheres in a free-molecule flow, *J. aero. Sci.* **18,** 5, 353–354, May 1951.

Purpose of note is to extend the heat-transfer calculations of Stalder and Jukoff [see AMR **1,** Rev. 1304] in the free-molecule flow régime of rarefied gas dynamics to include the case of heat transfer from spheres. From author's summary

Turbulence, Boundary Layer, etc.

(See also Revs. 4508, 4511, 4534, 4535)

4542. Young, A. D., Boundary layers and skin friction in high-speed flow, *J. roy. aero. Soc.* **55,** 485, 285–302, May 1951.

Author reviews the present knowledge of boundary layers at high speeds. Some general features of compressible boundary layers are first considered. This is followed by a discussion of some flow and thermal characteristics of laminar boundary layers and a discussion of problems concerned with turbulent boundary layers. Scale effects and shock-wave boundary-layer interaction effects are considered and illustrated with a number of figures and schlieren photographs. Paper should prove of considerable interest to workers concerned with viscous or thermal characteristics of high-speed flows. E. Bernard Klunker, USA

4543. Scherrer, R., Boundary-layer transition on a cooled 20° cone at Mach numbers of 1.5 and 2.0, *Nat. adv. Comm. Aero. tech. Note* 2131, 13 pp., July 1950.

The laminar boundary layer on a cooled 20° cone was investigated at Mach numbers of 1.5 and 2.0 to determine the variation of the position of transition with surface temperature for both constant surface temperatures and surface temperatures that increased toward the rear of the cone. Small circumferential grooves at the tip were necessary to cause transition near the center of the cone at the condition of zero heat transfer. The results obtained at all test conditions indicate that removing heat from the boundary layer delays transition from laminar to turbulent flow. The theory of laminar boundary-layer stability developed

by Lees [*NACA tech. Note* 1360, 1947], is in qualitative agreement with this result. At the test conditions of the present investigation, the increase in the extent of the laminar boundary layer was found to be a linear function of the rate of heat transfer.

From author's summary

4544. Bursnall, W. J., and Loftin, L. K., Jr., Experimental investigation of localized regions of laminar boundary-layer separation, *Nat. adv. Comm. Aero. tech. Note* 2338, 57 pp., Apr. 1951.

Paper describes low-speed ($M = 0.2$) tests to determine characteristics of regions of separated laminar boundary layers on NACA 66_3-018 airfoil at zero angle of attack. Experiments show occurrence of a length of separated laminar boundary layer followed by transition to a turbulent boundary layer which reattaches to surface. Extent of laminar run after separation is shown to be a function of Reynolds number based on boundary-layer thickness. Results are in agreement with previous tests made on other airfoils at small angles of attack. Lack of correlation between length of laminar run following separation for cases of small and high angle of attack suggests search for additional or different correlating parameters.

J. R. Stalder, USA

4545. Weil, H., Effects of pressure gradient on stability and skin friction in laminar boundary layers in compressible fluids, *J. aero. Sci.* **18,** 5, 311–318, May 1951.

Author extends von Kármán-Pohlhausen method to find approximate steady-state velocity and temperature in a compressible laminar boundary layer with a pressure gradient in the direction of flow. Assumptions are: (1) wall is heat-insulated, (2) viscosity is proportional to temperature, (3) adiabatic gas, and (4) Prandtl number one. Results are used to find effect of pressure gradient on skin friction, on momentum thickness, and, by a criterion due to Lees [AMR **3,** Rev. 485], on stability to small perturbations.

Numerical results are obtained for free-stream Mach numbers of 1.5 and 4 over a 5% thick biconvex airfoil. These show that the favorable effect of a negative pressure gradient is slight for Mach number 4, but is very pronounced for Mach number 1.5, while both cases show an up to 30% increase in drag over the flat plate. Curves showing behavior of the momentum and displacement thicknesses are also given. R. C. Roberts, USA

4546. Zaat, J. A., Revised methods for routine calculations of laminar and turbulent boundary layers of two-dimensional incompressible flows, *Nat. LuchtLab. Amsterdam Rap.* F.79, 14 pp., 4 tables, 3 figs., Nov. 1950.

Author has simplified Timman's one-parameter method by a linearization and modified the semi-empirical methods for turbulent boundary layers in accordance with experiments of Ludwieg and Tillman. By introducing a related revision of empirical law controlling variation of shape parameter, a method of calculation is obtained which gives clear indication of turbulent separation. The calculated separation point is shown to be almost independent of the chosen initial value of H. Alvin H. Sacks, USA

4547. Heisenberg, W., On stability and turbulence of fluid flows, *Nat. adv. Comm. Aero. tech. Memo* 1291, 60 pp., June 1951.

Translation of "Über Stabilität und Turbulenz von Flüssigkeitsströmen," *Annalen der Physik* **74,** no. 15, 1924.

4548. Munk, M. M., On turbulent fluid motion, *J. aero. Sci.* **18,** 7, 442–446, July 1951.

A mechanism that produces turbulence is now seen reasonably clearly (in two-plane channel flow). The counterrotational disturbance vortexes slow down in their race with the corotational vortexes on their way toward the walls, because positive cumulation is reserved for the corotational vortexes. This vortex discrimination leads to increased wall rotation and wall friction and, hence, to increased energy supply. Nothing indicates that the excess energy supplied is dissipated so uniformly as to exclude the formation of new disturbances. Thus, a foundation for continual turbulence is laid. The increasing velocity profile steepness near the wall finally leads to saturation of the vorticity and to statistical equilibrium.

From author's summary by Karl Wieghardt, England

4549. Reichardt, H., Representation of velocity distribution of turbulent flow in pipes (in German), *Z. angew. Math. Mech.* **31,** 7, 208–219, July 1951.

An improved theory for the mean velocity distribution in a pipe with a fully developed turbulent boundary layer is given. The theory is based on the idea of a "turbulent exchange coefficient" analogous to the coefficient of viscosity in laminar flow. The values of numerical coefficients and the variation of certain parameters are obtained from collected experimental results.

The final formula for the velocity distribution is symmetrical about the pipe axis and gives a value of velocity equal to zero at the wall, thereby improving the standard logarithmic formula obtained from the mixing length theory. In its final form the formula agrees extremely well with experimental results.

G. M. Lilley, England

4550. Krzywoblocki, M. Z., On complete forms in a turbulent three-dimensional flow of compressible viscous fluid, *Öst. Ing.-Arch.* **5,** 2, 129–137, 1951.

Author derives a sequence of generalized tensor and vector forms for stress and energy terms in a compressible three-dimensional turbulent medium. These are obtained by the Reynolds averaging procedure applied to the momentum and energy equations assuming mean and fluctuating contributions in the velocity, pressure, density, and temperature, and a temperature-dependent viscosity coefficient. Author uses mixing length theory without arguing its justification in the three-dimensional compressible case, or suggesting ways of estimating l. The general results, which are mainly of formal interest, are set out in tables and may be simplified for particular cases.

Lawrence M. Grossman, USA

4551. Tifford, A. N., and Wolansky, J., On the calculation of the rate of heat transfer through a laminar boundary layer, *J. aero. Sci.* **18,** 6, 427–428, June 1951.

L. Goland [AMR **3,** Rev. 1636] compared the results of four approximate heat-transfer methods with results of actually solving the laminar boundary-layer equations for the case of a particular isothermal cylinder. The present authors extend this comparison to include a fifth approximate procedure, namely Lighthill's (L), as modified by Tifford [AMR **4,** Rev. 3942]. The agreement with Goland's curve is quite satisfactory (as was true for Squire's method (S) [*Brit. Air Ministry Rep. and Memo.* no. 1986, 1942] in Goland's paper). Authors state that still another approximation, namely Dienemann's extension (D) [AMR **4,** Rev. 3602] of the Holstein-Bohlen-Pohlhausen method, also gives good agreement upstream of the point of minimum pressure.

Because approximations L, S, and D agree with each other and yield coefficients as much as 5% higher than Goland's, authors question the numerical accuracy of Goland's results and of this reviewer's calculations, on which they were based [AMR **1,** Rev. 483]. To be sure, these original data were never intended to be highly precise, although the reviewer would be surprised at

errors as great as 5%. Reviewer would conclude that approximations L, S, and D give satisfactory results, while the other approximations compared by Goland, showing errors of much greater magnitude, should be discarded. W. R. Sears, USA

4552. Sakurai, A., On the thickness of plane shock waves in a gas in turbulent motion, *J. phys. Soc. Japan* **5,** 114–117, 1950.

Author attempts to develop a theory to explain the thickness of the shock in terms of turbulent motion. While the basic ideas are sound, much simplification has to be made to carry out the details, as is generally the case with turbulence studies in a compressible fluid. C. C. Lin, USA

4553. Corrsin, S., The decay of isotropic temperature fluctuations in an isotropic turbulence, *J. aero. Sci.* **18,** 6, 417–423, June 1951.

Author studies the decay of random temperature fluctuations θ in a fluid under the action of thermal conduction and turbulent convection. An exact result, analogous to Loitsianskiĭ's invariant relation for the velocity fluctuations, is established, and this permits the deduction that θ^2 decays as $t^{-3/2}$ when the turbulent convection is negligible. In the case of convection which is so strong as to make conduction effects negligible for all except the small scale components, author follows von Kármán and Kolmogoroff in assuming self-preservation of the correlation functions (excluding the range in which conduction effects are significant), but no general results can be established. In all cases it seems likely that the temperature fluctuations decay less rapidly than the velocity fluctuations. G. K. Batchelor, England

4554. von Kârmân, Th., and Lin, C. C., On the statistical theory of isotropic turbulence, *Advances appl. Mech.* **2,** 1–19, 1951. [New York, Academic Press, Inc.]

After giving a simple systematic demonstration of the relation between the correlation theory and the spectral theory, authors discuss various considerations of similarity and a general comparison with experiments. An analysis of the spectrum is proposed. The theory, which has already been published in another paper [see AMR **3,** Rev. 2739], is made to fit with known experimental observations of wind-tunnel turbulence, and divides the process of energy decay in three stages: (1) early stage, (2) intermediate stage, and (3) final stage.

Rejecting Loitsianskiĭ's theorem, there exists for very high Reynolds numbers at least a one-parametric family of similar solutions, when the range of the largest wave numbers is excepted from the consideration of similarity. One of these solutions corresponds to Heisenberg's similarity hypothesis (case *c* of reviewed paper) with a linear part in the low frequency range of the spectrum. Another solution satisfies Loitsianskiĭ's relation and is called "the case of nonviscous similarity" (case *b*) [see J. Rotta, AMR **4,** Rev. 1686].

Authors propose that, for the early stage, Heisenberg's similarity hypothesis holds although, as they state, no a priori reason can be found why the decay should not start according to the law specified by the nonviscous similarity theory. Reviewer remarks that validity of Heisenberg's similarity hypothesis is, indeed, supported experimentally only by the observed law of decay. But there is no experimental evidence for a linear part of the spectrum. On the other hand, it is not exactly known whether the law of decay $u'^2 \sim t^{-1}$ is a typical property of isotropic turbulence at all or whether it takes place only when turbulence is produced by a fluid streaming through a mesh grid. Because of these open questions, reviewer believes that a rigorous examination of whether or not the theory satisfies the actual physical conditions in the early stage is hardly possible at the present time.

During the intermediate stage, authors suppose—in agreement with reviewer—that the case of nonviscous similarity prevails, if the initial Reynolds number is high. Due to this similarity hypothesis, the Reynolds number R_λ decreases with time and at least, when R_λ becomes so small that the energy transfer between the various wave numbers is considered to be negligible, the final stage sets in. This stage, in which full similarity exists, has been clarified before and is, therefore, not discussed.

Julius Rotta, Germany

Aerodynamics of Flight; Wind Forces

(See also Revs. 4512, 4514, 4532, 4584)

4555. Campbell, J. P., and McKinney, M. O., Summary of methods for calculating dynamic lateral stability and response and for estimating lateral stability derivatives, *Nat. adv. Comm. Aero. tech. Note* 2409, 97 pp., July 1951.

Summary is presented of methods for making dynamic lateral stability and response calculations and for estimating the aerodynamic stability derivatives required for use in these calculations. Authors outline procedure for calculation of time histories of lateral motions, of period and damping of these motions, and of lateral stability boundaries. A comprehensive list of references is given to work mainly of NACA, both experimentally and theoretically, which may be used in making estimates of various lateral stability derivatives. While paper presents detailed estimation methods for low-subsonic-speed conditions, only brief discussion and a list of references are given for transonic and supersonic speed conditions.

From author's summary by S. Lampert, USA

4556. Spence, A., Further wind-tunnel tests on the effects of ice accretion on control characteristics, *Aero. Res. Counc. Lond. curr. Pap.* 43, 6 pp., 6 figs., May 1950, published 1951.

Tests conducted on a tail plane using transition wires and four different types of simulated icing conditions indicate that the location of the transition point is the important factor in this study and that it has a considerable effect on the rate of change of hinge moment with flap angle on flaps having large trailing-edge angles. Robert S. Ross, USA

4557. Kraft, C. C., Jr., and Assadourian, A., Experimental study of an angle-of-attack vane mounted ahead of the nose of an airplane for use as a sensing device for an acceleration alleviator, *Nat. adv. Comm. Aero. tech. Note* 2415, 8 pp., July 1951.

An investigation was made to determine the ability of a vane, mounted ahead of the nose of an airplane, to give an indication of the average angle of attack over the entire wing span during flight through rough air. These tests were performed to determine the suitability of such a vane as a sensing device for an acceleration alleviator. The results show that the vane gives a sufficiently accurate measure of the average angle of attack over the wing span to be of use for this purpose, though rapid fluctuations in angle of attack caused by small-scale turbulence would have to be filtered from its output. From authors' summary

4558. Johnson, J. A., and Eustis, R. H., An analysis of helicopter propulsion systems, *Trans. Amer. Soc. mech. Engrs.* 73, 5, 519–527, July 1951.

This notable contribution presents a comparative analysis of several lightweight torque, jet-reaction, and reciprocating-engine propulsion systems based on hovering, duration, and maximum range. The systems investigated are divided into

three groups: (1) Geared-engine power plants, (2) reaction jet supplied by fuselage-located gas generators, and (3) jet engine located at the rotor-blade tips. Wherever possible, the engine performance data used in the computations have been taken from available experimental values, and the helicopter configuration and component weights were assumed to comply with present operational aircraft.

A few of the resulting conclusions are: (a) Geared-engine power plants appear to offer the greatest endurance and range; (b) the geared gas-turbine engine offers the possibility of increased endurance and useful load for flights less than 500 miles as compared to the conventional reciprocating engine; (c) of the second group mentioned above, the turbine-gas generator offers considerable promise for flight ranges up to 700 miles and for short-range flight (200 miles). An increase in useful load of 60% appears possible; (d) from the standpoint of maximum range and endurance the V-1 type of pulse jet operating at a low speed provides a greater useful load than the geared reciprocating engine for a flight range less than 120 miles or an endurance of 1.4 hr.

While the results are in general agreement with present qualitative ideas on the subject, the quantitative results presented should prove valuable. Authors are to be commended for a very logical presentation to the often distorted comparison-type analysis. Leonard Goland, USA

4559. Mickleboro, H. C., and Shufflebarger, C. C., Flight investigation of the effect of transient wing response on wing strains of a twin-engine transport airplane in rough air, *Nat. adv. Comm. Aero. tech. Note* 2424, 21 pp., July 1951.

Flights were made in clear-air turbulence for different wing fuel loads and for two speed conditions at altitudes between 3000 and 4000 ft. Slow pull-ups were made in smooth air to obtain data for a reference quasistatic condition. Simultaneous measurements were made of nodal-point acceleration and of wing strains at a number of spanwise stations.

The bending strains per unit normal acceleration in gusts were approximately 20% higher than those in slow pull-ups for all measuring positions and flight conditions of the tests. The dynamic component of the wing-bending strains appeared to be due primarily to excitation of the fundamental wing-bending mode. The data on spar-web strain exhibited a rather large amount of scatter, and the estimated web-strain amplifications for gusts relative to pull-up conditions varied considerably with measuring station. From authors' summary

4560. Donely, Ph., Summary of information relating to gust loads on airplanes, *Nat. adv. Comm. Aero. Rep.* 997, 51 pp., 1950.

See AMR **3,** Rev. 1557.

4561. Liepmann, H. W., An approach to the buffeting problem from turbulence considerations, *Douglas Aircr. Co. Rep.* SM-13940, 23 pp., 2 figs., Mar. 1951.

As a simple example to illustrate a principle, author considers the root-mean-square lift on a two-dimensional airfoil in turbulent air. In the analysis, the lift due to a sinusoidal gust is needed; this was provided by Sears [*J. aero. Sci.* **8,** 104–108, 1941]. Sears' result is approximated in simple form, so far as the absolute magnitude of the lift is concerned, irrespective of phase. Assuming the turbulence to be isotropic, its power spectrum is written in a relatively simple expression, and the mean-square lift coefficient is calculated. Certain limiting cases are considered as examples. An approximate correction for spanwise variation of the gusts can be made by imitating the "length correction" for hot-wire anemometers. This involves the space correlation of the turbulence. Finally, the effects of wing elasticity are considered briefly. There is an appendix on correlation functions and power spectra, and an introductory article on the response of mechanical systems, in general, to random forces. W. R. Sears, USA

4562. Naylor, C. H., 24-ft tunnel tests on a high-lift model. Downwash and velocity measurements at the tailplane, *Aero. Res. Counc. Lond. Rep. Mem.* 2649, 3 pp., 4 figs., Mar. 1942, published 1951.

Pitching moment measurements in the 24-ft tunnel have shown that the high-lift model with double Fowler flaps down and slat open, although reasonably stable without slipstream, becomes unstable at the higher thrust coefficients required for level flight and climb. In some cases the tail plane contributed nothing to the longitudinal stability of the model. The present tests have been made to investigate the air flow in the neighborhood of the tail plane.

The variation in downwash angle and velocity is such as to make the tail plane a destabilizing rather than a stabilizing member, at constant throttle with the flaps and slat in operation with the tail plane in any practicable position. This is due to the large downwash angles associated with the relatively low-aspect-ratio wing. The stability could be improved by the use of a higher-aspect-ratio wing. The effect of slipstream on the complete airplane, however, is not necessarily destabilizing with flaps down because of the favorable effects of a high thrust line and of the slipstream velocity over the wing and flaps.

From author's summary

4563. Etkin, B., and Woodward, F. A., Calculation of maneuvering tail loads by the inverse method, *Nat. Res. Counc. Canad. aero. Rep.* AR-8, 25 pp., 1951.

A method is presented for calculating horizontal tail loads in pull-up maneuvers from horizontal flight. Linearized equations of motion, as in classical longitudinal stability theory, are used, the fore-and-aft degree of freedom being eliminated by the assumption of constant airplane speed. The time history of the normal load factor is assumed and the corresponding elevator deflection and tail-load variation are calculated. In choosing a suitable time history of load factor, it is necessary to decide upon a reasonable time to the first maximum elevator deflection. Computed results are found to agree closely with flight-test results. The chief advantage of the method, as compared with one involving assumption of an elevator-deflection pattern, lies in its ease of application. Gabriel Isakson, USA

4564. Diederich, F. W., A planform parameter for correlating certain aerodynamic characteristics of swept wings, *Nat. adv. Comm. Aero. tech. Note* 2335, 17 pp., Apr. 1951.

To correlate total aerodynamic characteristics on sweptback wings of finite span in subsonic flow, the aspect ratio is replaced by a parameter which takes account of the influence of angle of sweepback and section-lift coefficient. The parameter is fully established by experimental results.

Maurice Holt, England

4565. van Heemert, A., The calculation of the downwash of sweptback wings in the region of the tail unit, *Nat. LuchtLab. Amsterdam Rap.* F.73, 17 pp., 1950, published 1951.

By representing a swept wing by a bent lifting line, and applying Biot-Savart's law, author computes downwash and the first few vertical and spanwise derivatives along the line of symmetry of the wing in the plane of the wing for arbitrary lift distribution. Results are expressed in terms of untabulated universal functions. Prandtl-Glauert transformation accounts for compressibility.

Theodore R. Goodman, USA

4566. Schlichting, H., Saving power in formation flights, *David W. Taylor Mod. Basin Transl.* 239, 38 pp., Apr. 1951.

The mutual influence of the individual aircraft of a formation is investigated with the aid of the Prandtl airfoil theory. Each aircraft generates in the region about it an upwash which, for a suitable formation of the aircraft, is utilized as a reduction in drag and thereby a saving of power. This saving of power can be transformed into a saving of fuel corresponding to the flight distance considered or an increase in flight range for a specified fuel consumption. For horizontal flight, the saving of power is proportional to c_{wi}/c_w, ($c_{wi}/c_w \doteq 1/10$), and therefore is small for the cruising configuration. Still, on the occasion of flight for engine throttled-down ($c_{wi}/c_w \doteq {}^1/_2$), the saving of power is considerable. General formulas are given for arbitrary arrangement of the aircraft flying in formations symmetrical with the flight direction. Numerical values are given for several cases. The power saving is strongly dependent upon the transverse distances between the aircraft. The most suitable arrangement of the aircraft is a V-formation with the vertex at the front. For such a formation, with the transverse distance between aircraft equal to one wing span and flying with throttle down, the average saving of power for three aircraft amounts to 14%, for five aircraft to 18% and for seven aircraft to 20%, when compared to the power required for single flight.

From author's summary by Vernon J. Rossow, USA

4567. Chaplígin, S. A., Selected works on wing theory (in Russian), Moscow-Leningrad, Gosud. Izd. tekh.-teor. Liter., 274 pp., 1949.

Much of the material in the six papers selected by S. A. Kristianovich is primarily of historical interest; much has been absorbed into textbooks and become classical. In the first pioneering work: "Forces on bodies immersed in a parallel stream" [*Matematicheskiĭ Sbornik*, 1910] Chaplígin deepens the understanding of life propounded by his teacher Joukowsky and develops the main features of general airfoil theory by the complex variable approach. In particular, he derives the lift and moment formulas known under the name of Blasius and produces a family of airfoils by inversion of parabolas, now constructed more simply and known as Joukowsky airfoils. The flow field in the plane of z outside the airfoil is mapped conformally on the upper half plane of u, so that $u \to \infty$ corresponds to the trailing edge and $z \to \infty$ to $u = \alpha$. Usage of the reflection principle to make the complex potential real on the real u axis and the study of its singularity at $u = \alpha$ lead to the main results. Complete solution is also obtained for a skeleton circular-arc airfoil with a small circular knob at the nose. In the discussion of this example, Chaplígin states that the validity of the lift formula ceases when local Mach number of unity is reached as the angle of attack is increased and infers that a regime (equivalent to the present concept) of stall sets in. For higher angles, he believes Rayleigh's jet formula predicts the force. A section is devoted to the study of the effects on the lift of a circular-arc airfoil of the nearness of a stationary unrestrained vortex. A decrease in lift is obtained, but the result is depreciated as being merely of theoretical interest. Finally, complicated modifications of the Joukowsky airfoil are mentioned; for instance, the lower surface can be made wavy in a special manner so as to increase the lift.

"Results of theoretical treatment of airplane motion" [*Bull. Moscow aero. Inst.*, 1910] discusses the physical concepts of the first paper. "On the general theory of a monoplane wing" (1922) is available in English [Paris, Gauthiers-Villars, 1929]. After making the 1910 concepts more precise and applicable to general airfoils, Chaplígin discusses their stability by means of the metacentric parabola. Aware of the impracticality of the cusped trailing edge of the Joukowsky airfoil, he rounds it off by a small perturbation of the mapping function and discusses the results. Finally, by adding simple poles in the lower half plane of u to the previous mapping function for z, he proposes a broad class of airfoils constructable by means of a pair of compasses and a ruler. Detailed study is made of the particular case of inverses of ellipses so obtained.

In "Effects of parallel air stream on moving two-dimensional wings" [*Works of Central Aerodynamic Institute*, no. 19, 1926] Chaplígin extends the complex variable approach (including the Blasius formulas) to unsteady flows with *constant* circulation. Expressions for lift and moment of general shapes are developed on the basis of admissible singularities of the mapping and potential functions, and the kinetic energy of the noncirculatory part of the motion is given. The mean values of these three quantities are found for harmonic motion. Application is made to elliptic, flat, and circular-plate profiles.

"Theory of cascades" [*Mat. Sborn.* 1914] rests on mapping the flow region around a staggered lattice of flat plates onto an infinite strip. Approximate discussion of lattices of very small and very large stagger is given. Perturbations of the mapping function allow camber and round leading edges, but corresponding routine calculations of forces and moments are omitted. Chaplígin's early concern with cascades appears to stem from a desire to improve lift and stability characteristics of wings by introducing slots; at first, the infinite lattice was to approximate a slotted airfoil. In the last paper, "Theory of slotted airplane wing" [1921; available in English, Paris, Gauthiers-Villars, 1929] the complex velocity fields around arbitrarily slotted flat and circular profiles are constructed directly by means of special functions which reduce to real values on the segments corresponding to partial chords of the airfoil. [These were partly rediscovered by E. Pinney, *Quart. appl. Math.* **VI**, no. 1, 1948.] Considerable increase in lift is indicated by proper choice of position and width of a single slot. More important, study of the metacentric parabola shows how the stability of the airfoil can be increased by proper slotting.

V. Morkovin, USA

4568. Rott, N., On the efficiency of wing-tip-flaps (in German), *Z. angew. Math. Phys.* **2**, 3, 208–212, May 1951.

Low-aspect-ratio control surfaces treated are on assumption of concentrated tip vortex from wing. Formulas are developed for lift and moments in terms of wing circulation. Author concludes that induced incidence due to vortex overshadows geometrical incidence.

John W. Miles, New Zealand

4569. King, J. C., and Trollope, D. H., A method of testing smooth wings for initial shape and resistance to distortion under load, *Aero. Res. Counc. Lond. Rep. Mem.* 2531, 6 pp., May 1945, published 1951.

4570. Howard, D. A., Bench-test investigation of the transient-response characteristics of several simulated airplanes incorporating an autopilot sensitive to yawing accelerations, *Nat. adv. Comm. Aero. tech. Note* 2395, 27 pp., July 1951.

From the results of tests conducted on an acceleration-sensitive autopilot combined with each of four simulated airplanes, the following conclusions are drawn: (1) An actual autopilot sensitive to angular acceleration did not produce an unstable high-frequency mode of motion of an airplane-autopilot combination. The occurrence of such an unstable mode of motion was predicted in a previous theoretical analysis when the autopilot was assumed to have a constant time lag and a constant amplitude ratio. (2) In the frequency range covered in the tests (from 0 to approximately 3 times the natural frequency of the autopilot), the phase

angle of lag of the test autopilot has values such that the autopilot could not produce a decrease in the damping of an airplane. (3) As a result of the rapid decrease of the autopilot amplitude ratio with frequency above its natural frequency, the yawing moments contributed by the autopilot to the airplane at relatively high frequencies with respect to the autopilot natural frequency were small. (4) The assumptions of a constant time lag and amplitude ratio do not satisfactorily approximate the frequency-response characteristics of other existing autopilots at high frequencies. When the concept of constant time lag is used, therefore, care must be exercised in applying results to a practical case. From author's summary

4571. Contensou, P., Application of methods of mechanics of a directed moving body to the theory of gliding flight (in French), *Bull. Assn. tech. marit. aéro.* no. 49, 279–322, 1950.

Paper deals with the determination of special families of limit trajectories interesting for gliding flight and defined as follows: Consider a glider occupying a given position P_1 at an initial time t_1. According to initial conditions and to pilot's maneuver, many terminal positions P_2 are possible at a posterior time t_2. They range, if motion in a vertical plane is considered, in a closed area. Limit trajectories are those leading the aircraft from P_1 to the particular points P_2 which belong to the boundary of the aforementioned area.

Following hypotheses are used: Bidimensional motion; homogeneous atmosphere; negligible rotational inertia; aerodynamic coefficients independent of both Mach and Reynolds numbers; negligible aerodynamic lag. The stated problem is solved by a graphical analytical method.

In reviewer's opinion, article has a peculiar mathematical and geometrical interest; but its practical importance is limited because of the basic hypotheses and large amount of required calculations. Angelo Miele, Argentina

4572. Seacord, C. L., Jr., Application of frequency-response analysis to aircraft-autopilot stability, *J. aero. Sci.* **17,** 8, 481–498, August 1950.

A description of the frequency-response method for analyzing an aircraft-autopilot combination is given, and examples are used to demonstrate various aspects of the method and the criteria for stability. In particular, one numerical example illustrates the method of calculating the aircraft response curves. The procedure for determining the autopilot response curves is outlined. The use of Nyquist diagrams for the analysis of frequency-response data is discussed, and Nyquist diagrams for the example are correlated with the separate frequency-response curves. The complete longitudinal and lateral equations of motion for an aircraft are presented, and, in addition, certain simplified equations for special cases are included. Sources of information concerning the aerodynamic derivatives are given in tabular form. From author's summary

4573. Luskin, H., and Lapin, E., An analytical approach to the fuel sloshing and buffeting problems in aircraft, *Douglas Aircr. Co. Rep.* SM-14068, 46 pp., June 1951.

Analytical approaches to two problems in aircraft dynamics are presented. A method is proposed for including the sloshing effects of a partially filled tank in the equations of longitudinal motion. The method uses the results of studies by E. W. Graham on rectangular tanks based on linearized expressions for the velocity potential given by Lamb. These results show that the fuel in its fundamental mode can be replaced by a simple pendulum. Inclusion of the effects of the fundamental mode of the fuel in the longitudinal case shows that the motion of the aircraft is composed of three loosely coupled oscillations: the phugoid, the short period, and the fuel natural mode. Significant damping in the fluid is shown to occur only in the case when baffles are present.

The airplane buffeting problem is discussed from the point of view that the flow in the wake is stochastic, and that statistical methods are therefore appropriate for the analysis of buffeting. Previous work by H. W. Liepmann on this subject is described. R. L. Bisplinghoff, USA

Aeroelasticity (Flutter, Divergence, etc.)

(See also Revs. 4366, 4561, 4573)

4574. Scanlan, R. H., and Rosenbaum, R., Introduction to the study of aircraft vibration and flutter, New York, The Macmillan Co., 1951, x + 428 pp. $7.50.

To reviewer, this book fills a real need in the present-day engineering literature. It is well written, and the experiences of the authors, as given in the various general discussions, agree remarkably well with those of the reviewer. In some details, however, reviewer disagrees with the authors.

The first five chapters cover general topics such as basic mathematics and fundamental vibration theory. Since this material is readily available in a great many existing reference books, reviewer believes that the 123 pages spent on this material could have been reduced to a short chapter on definitions. In the section on damping, authors make the correct statement that when damping is introduced by replacing the spring constant k by $k(1 + ig)$ the damped frequency of free vibration becomes higher than the natural frequency. However, this is due to the fact that the expression $1 + ig$ does not really represent any physical type of damping but is merely an approximation, for small values of g, to the correct expression $\exp ig = \cos g + i \sin g$, which is based on the hysteresis loop of the material. If the correct expression is used for this type of damping it would be found that, for small g, the value of ω_d would be identical with that for a viscous damping factor $c/c_c = g/2$.

Chapter VI treats basic beam-structural relationships and chapter VII uncoupled beam vibration. In the latter chapter, reviewer believes that authors have overstressed the importance of the matrix iteration method, particularly as applied to higher modes. Since higher modes are useless unless a sufficiently large number of stations are used (at least four stations for each mode desired), the matrix-iteration method quickly becomes unduly cumbersome.

Chapters VIII, IX, X, XII and XIII deal with two- and three-dimensional incompressible-flow flutter theory of both wing and tail, while chapter XIV deals with the problems of torsional divergence and aileron effectiveness. In reviewer's opinion, these are the best chapters of the book. Reviewer is disappointed in chapter XI, which treats the important problem of natural modes of wing vibration, since only the most cumbersome method for finding these modes is given.

Chapter XV deals with instrumentation and testing, while chapter XVI is a brief treatment of vibration and flutter of a swept wing. Reviewer likes chapter XV but believes chapter XVI is a little too short.

Chapter XVI is followed by an excellent bibliography and six appendixes dealing with the aerodynamics of flutter.

N. O. Myklestad, USA

4575. Woolston, D. S., and Runyan, H. L., On the use of coupled modal functions in flutter analysis, *Nat. adv. Comm. Aero. tech. Note* 2375, 13 pp., June 1951.

Authors discuss the use of coupled modal functions vs. un-

coupled modes in a Rayleigh-type flutter analysis by means of numerical examples and comparison with experimental results. For various combinations of modes, two conclusions are drawn. The use of uncoupled modes, in general, provided as accurate results as the more tedious calculation involving coupled bending-torsion modes. Good agreement with experimental results is achieved in either case through the use of two-dimensional airforce coefficients and the differential-equation approach to the structural analysis. James B. Duke, USA

4576. Naylor, G. A., An approximation simplifying wing flutter calculations, *Aero. Res. Counc. Lond. Rep. Mem.* 2605, 10 pp., Apr. 1942, published 1951.

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 4499, 4515, 4606)

4577. Anastasi, A., Elementary theory and calculation of the "Vulcan" hydraulic coupling (in Italian), *Termotecnica* **5**, 1, 20–24, Jan. 1951.

Author assumes blade number as infinite and fluid motion as following the mean revolution surface between the external and internal surfaces, limiting the blades in two rotors forming the hydraulic coupling. He is thus allowed to study the motion as a unidimensional one. Further extremely simplifying assumptions about turning angles imposed by blades and energy losses allow, through moment of momentum and energy equations, to relate transmitted couple, flow rate, and slip between rotors in a very simple manner. Carlo Ferrari, Italy

4578. Thompson, J. S., Smelt, R., Davison, B., and Smith, F., Comparison of pusher and tractor propellers mounted on a wing, *Aero. Res. Counc. Lond. Rep. Mem.* 2516, 18 pp., June 1940, published 1951.

4579. Hausenblas, H., Experiments with turbine blade-cascades (in German), *Ing.-Arch.* **19**, 2, 75–82, 1951.

Deflections and total pressure losses were measured for different cascade arrangements and three different profile families. Results are illustrated by means of plots showing the lift coefficient times chord-to-pitch ratio versus incidence, and the "glide angle" versus incidence. The profiles with steady curvature variation of suction-side profile shape are shown to have smaller losses and higher deflections than profiles with sudden variations of curvature. Pressure distributions on the profiles are shown, and the influence of turbulence on loss factors is determined.

E. Haenni, Switzerland

4580. Himmel, S. C., and Krebs, R. P., The effect of changes in altitude on the controlled behavior of a gas-turbine engine, *J. aero. Sci.* **18**, 7, 433–441, July 1951.

Paper presents theory of engine dynamic response variation with altitude and some experimental data tending to corroborate the theory. An electric analog computer is used to illustrate changes in engine dynamics with altitude, and it is shown that the response at altitude may be computed from data obtained at sea level. Authors conclude it is necessary to vary the gain and time variant parameters of the control loops with altitude if satisfactory performance is to be obtained.

A. F. W. Langford, Australia

4581. Sleeswijk, A. W., Eccentric rotary pumps (in Dutch), *Ingenieur* **63**, 1, 3; W.1–W.8, W.11–W.17; Jan. 1951.

In cases where plunger pumps are recommended, the simplicity of design and the increasing use of electric power often may cause this kind of rotary pump to be of interest. Article gives a description of the known types and possibilities of these pumps.

From author's summary

4582. Peterman, H., Turbo blowers with inward flow runner (in German), *Forsch. Geb. Ing.-Wes. Ausg. B*, **17**, 2, 51–59, 1951.

Paper analyzes the performance of compressors with radial inward flow and presents performance curves over a range of different impellers and diffusers. The basic equations show that the radial extension of the impeller must be small and the impellers have a radius ratio of 1.125.

Tests showed that the best impeller inlet and exit angles are $\beta_1 = 15°$ and $\beta_2 = 60°$, respectively. The optimum efficiency of the compressor was 64%. In order to establish centripetal flow, exit guide vanes are necessary under all conditions.

With radial inward flow and increasing pressure gradient in the inward direction, removal of the boundary layer does not occur in as simple a manner as in a centrifugal compressor where centrifugal force acting on the boundary layer and the general direction of flow go in the same direction. It may therefore be expected that boundary layers of large magnitude exist in a centripetal compressor. In addition, a displacement flow exists for impeller with finite number of blades. The above conditions result in a recommendation that the width at the entrance to the exit guide vanes shall be larger (1 to 1.4 times) and the optimum entrance angle should be smaller (0.60 to 0.70 times) than the calculated values. The tests also indicate that a shroud is strongly recommended. Without a shroud the instability of operation is increased. The clearance between impeller and exit guide vanes must be small for good efficiency but causes considerable noise. As expected, the centripetal compressor follows the similarity laws.

The range of pulsation is on the same order as that of similar centrifugal compressors. However, a new phenomenon was observed indicating that in the range of pulsation three pressure-volume curves are possible, one being stable and two being labile in nature. Tests indicate that pressure coefficient and efficiency of the centripetal compressor are below corresponding values for the centrifugal compressors. H. E. Sheets, USA

4583. Stanitz, J. D., and Prian, V. D., A rapid approximate method for determining velocity distribution on impeller blades of centrifugal compressors, *Nat. adv. Comm. Aero. tech. Note* 2421, 31 pp., July 1951.

Knowledge of velocity distribution along blade surface is important because of its effect on viscous losses, surging, and choke. Paper develops rapid method of calculating this distribution (but not distribution between blades) for compressible or incompressible, nonviscous fluid and blade of arbitrary shape. Equations are of quasi three-dimensional type, being combination of two types of two-dimensional solution, one for flow in an axial-radial plane (axial symmetry), the other for flow on surface of revolution generated by streamline. Only the latter solution is discussed in detail here, the other having been given in previous publications. Application of equations to eight widely varying cases resulted in numerical values agreeing closely with those given by relaxation methods, except near impeller tip. C. W. Smith, USA

4584. Wattendorf, F. L., Simplified design comparisons of axial compressors, *J. aero. Sci.* **18**, 7, 447–459, July 1951.

Following axial compressor designs are compared, with particular emphasis on the attainment of high mass flows: (1) Free vortex principle with positive and negative prerotation; (2)

rigid body positive prerotation design; (3) maximum constant rotor work without specification of prerotation type; (4) nonconstant distribution of rotor work over radius. Since the inlet stage is usually critical for mass flow, it alone is considered. Influence of hub-tip ratio and axial Mach number on stage-pressure ratio within assumed limitation of relative and absolute Mach number only is first studied. Aerodynamic blade-loading limitation according to Keller's proposition $\sigma \cdot C_L \leqq 1, 2$ is then introduced showing substantial diminution of attainable stage-pressure ratios for all design types. Most of the results are familiar to turbojet-engine designers: Free vortex flow with positive prerotation is not suitable for high mass-flow and stage-pressure-ratio; free vortex flow with negative prerotation is capable of high mass-flow but has still low stage-pressure-ratios; rigid body positive prerotation results in higher values of pressure rise than free-vortex principle over the usual range of mass flow, while nonconstant rotor work type gives high stage-pressure rises up to extremely high mass-flow ratios. Corresponding formulas are derived in an appendix. Pierre Schwaar, Switzerland

4585. Michel, D. J., Ginsburg, A., and Mizisin, J., Experimental investigation of flow in the rotating passages of a 48-inch impeller at low tip speeds, *Nat. adv. Comm. Aero. Res. Memo.* E51D20, 37 pp., June 1951.

The flow is tested within the rotating passages of a 48-in. radial impeller at tip speeds of 500 and 700 fps by use of a suitable pressure-transfer device to transmit the pressure from the rotating passages to the stationary measuring station and which may prove to be a valuable extension of test techniques.

In the range tested, the pressure coefficients were found to be similar. The pressure was measured across the passage. Along the trailing face the efficiency was found to be diminished, otherwise the pressure distribution corresponded to the theoretically computed one. Power input and pressure integral were found to correspond to each other.

In particular, static pressure along the blades, total and static pressure across the passages have been determined. Increasing the flow toward maximum flow resulted in separation from the driving face as the result of the too large negative incidence angles. The separation of the flow then proved to be accompanied by secondary flow phenonena which increased the total pressure losses. F. Weinig, USA

4586. Wilcox, E. C., and Trout, A. M., Analysis of thrust augmentation of turbojet engines by water injection at compressor inlet including charts for calculating compression processes with water injection, *Nat. adv. Comm. Aero. Rep.* 1006, 20 pp., 1951.

A psychrometric chart and Mollier diagram for saturated water-air mixtures are presented. At zero Mach number and a compression ratio of 4.61, water injected into compressor-inlet saturated air to yield outlet saturated air increases the thrust 24%. The augmented thrust increases rapidly as the flight Mach number is increased. Only a theoretical thermodynamic analysis was made and none of the practical problems such as attainment of equilibrium, dispersion of water into air, or the effect on compressor efficiency are considered. H. E. Robison, USA

4587. Otto, E. W., and Taylor, B. L., III, Dynamics of a turbojet engine considered as a quasi-static system, *Nat. adv. Comm. Aero. tech. Note* 2091, 35 pp., May 1950.

A determination of the dynamic characteristics of a typical turbojet engine with a centrifugal compressor, a sonic-flow turbine-nozzle diaphragm, and a fixed-area exhaust nozzle is presented. A generalized equation for the transient behavior of the engine was developed; this equation was then verified by calculations using compressor- and turbine-performance charts extrapolated from equilibrium operating data and by experimental data obtained from an engine operated under transients in fuel flow.

The results indicate that a linear differential equation can be written for engine acceleration as a function of fuel flow and engine speed for operation near a steady-state operating condition. The coefficients of this equation can be obtained either from actual transient data or with a fair degree of accuracy from the steady-state performance maps of the compressor and turbine, and can be corrected for altitude in the same manner that steady-state performance data are corrected. From authors' summary

4588. Mock, F. C., Turbojet and turboprop engine controls, *Soc. auto. Engrs. quart. Trans.* 5, 3, 376–391, July 1951.

The gas-turbine control situation is in a bad state of confusion, author feels, because of such factors as the newness of gas-turbine development, the lack of comparative evaluation tests on controls, and the lack of time for the results of field experience to become generally known among administrative personnel as to the importance of their many complex characteristics.

Author analyzes the present status of jet controls and answers the following questions concerning them: (1) What are their functional requirements? (2) What are the factors involved in power selection? (3) What are the requirements for transitional control? (4) What are the types of compressor stall? (5) How can a simple control device be built so that engine parameters are safeguarded and yet engine efficiency is maintained?

Author makes the following conclusions in summarizing the necessary steps for designing controls: (1) The whole control function must start from throttle position; the same throttle position must presumably give the same percentage of maximum rpm at all altitudes and temperatures. (2) At all altitudes and entering air temperatures, the maximum acceleration possible without overtemperature or blow-out is desired. (3) An empirically scheduled stall limit of fuel flow must be applied, with a different scale of entering air-temperature compensation, or at least a different set of metering parameters, from that of preceding (1) and (2). (4) Some graduation of minimum flow with altitude is probably necessary to avoid flame-out. (5) To avoid a practically impossible degree of complication, the same method of temperature and altitude compensation should be employed as nearly as possible on all the above functions. (6) Since, in actual practice, it has not been possible to determine exactly the engine requirements until some engines are in flight service and until a considerable number of controls have been built, it is necessary that the control is designed to be flexible and easily adaptable in setting. (7) The various regulations listed above should be readily adaptable to changes in viscosity, density, and heat content of the fuel. (8) The control unit should operate safely all the way from a temperature so high that the fuel boils, to the low extreme where the synthetic rubber packings become hard; and with increments of desert sand, ocean salt water, and arctic petroleum-wax slush in the fuel.

Ammon S. Andes, USA

4589. Henry, J. R., and Bennett, J. B., Method for calculation of ramjet performance, *Nat. adv. Comm. Aero. tech. Note* 2357, 95 pp., June 1951.

Thrust coefficient of ramjet for any fuel-air ratio, intake-diffuser total-pressure-recovery ratio, and flight Mach number is expressed in terms of a mass-flow parameter, a heat-addition parameter, and a pressure-loss parameter. Values of these parameters are plotted in convenient charts as functions of "basic

variables" (flight Mach number, combustion-chamber characteristics, intake-diffuser and exhaust-nozzle total-pressure-recovery ratios). Correcting procedures are presented to account for changes of specific-heat ratio and gas constant. Corrections are found to be of same order as errors introduced by assumption of one-dimensional flow. Joseph V. Foa, USA

4590. **Davis, H., Kottas, H., and Moody, A. M. G., The influence of Reynolds number on the performance of turbomachinery,** *Trans. Amer. Soc. mech. Engrs.* **73,** 5, 499–503, July 1951.

The over-all duty of a turbomachine with respect to fluid-friction effects is measured by a certain machine Reynolds number. Experimental data are presented for several types of turbomachines which show the variation in over-all efficiency with this Reynolds number when all other dimensionless parameters are held constant. The results are conclusive for the ranges of data reported, and should be useful to design, application, and operating engineers confronted with unfamiliar Reynolds number values. R. C. Binder, USA

4591. **Nagey, Tibor F., Comparison of turbine-propeller engines with various cycle arrangements for subsonic flight speeds,** *Soc. auto. Engrs., Special Publ. Dept.*, 17 pp., Sept. 1950 = *Soc. auto. Engrs. quart. Trans.* **5,** 3, 316–326, July 1951.

In gas-turbine power plants for land and marine use, regeneration and reheat are of crucial importance. In aircraft-engine design, especially for turbine-propeller engines, the question arises whether improvements are possible in airplane performance when using more complicated cycle arrangements than the basic. Paper analytically compares basic, reheat, regenerative, and regenerative-plus-reheat turbine-propeller engines in the flight speed range 200–600 mph at altitudes 0–50,000 ft at various compressor-pressure ratios and turbine-inlet temperatures, showing theoretically possible improvements. Gillis Huss, Sweden

Flow and Flight Test Techniques

(See also Revs. 4388, 4505, 4523, 4562, 4636)

4592. **Jones, M., and Bright, P., Theoretical velocity distribution in a high-speed tunnel contraction,** *Aero. Res. Counc. Lond. Rep. Mem.* 2601, 10 pp., Oct. 1945, published 1951.

4593. **Lowell, H. H., Design and applications of hot-wire anemometers for steady-state measurements at transonic and supersonic airspeeds,** *Nat. adv. Comm. Aero. tech. Note* 2117, 106 pp., July 1950.

An investigation was made of the design requirements and heat-transfer characteristics of exposed-wire instruments to be used for steady-state measurements at transonic and supersonic speeds. Design criteria, construction details, and typical response behavior are presented. Several types of instruments were evolved that, in addition to exhibiting the required high stability, are capable of providing steady-state mass-flow, flow-angle, and temperature information of engineering accuracy at total temperatures at least as high as 275 C, Mach numbers at least as great as 2.4, and air total densities at least as great as twice atmospheric. Heat-transfer data for a circular cylinder over at least the Mach number range from 0 to 2.4 may be correlated by addition to the conventional relation among Nusselt, Prandtl, and Reynolds numbers of a factor that is a function of Mach number only. Finally, it is shown that the combination of an air-temperature datum (obtained with a wire), a wire heat-loss datum, and a pressure datum limited to pressures not exceeding static by more than about 20% of the velocity head uniquely specifies a steady-state flow. From author's summary

4594. **Riegels, F., Correction factors for wind tunnels of eliiptic section with partly open and partly closed test section,** *Nat. adv. Comm. Aero. tech. Memo.* 1310, 18 pp., Mar. 1951.

Two problems are treated: (1) An arc of the cross-sectional ellipse, symmetrically located to its minor axis, is rigid; (2) two such arcs, symmetric to the major axis, are rigid. In both cases the working section is assumed infinitely long so that the analysis can be carried out in the plane $x = -\infty$ (Trefftz plane). By successive mappings that involve the function $sn(a \arcsin bz)$, the ellipse is mapped into a strip in problem (1) and into a rectangle in problem (2) such that rigid and free arcs appear as straight boundaries. The wing is assumed to have constant lift distribution and appears, therefore, as a pair of vortexes in the Trefftz plane. The boundary conditions are enforced by reflection as usual, and the additional downwash due to the image vortexes is computed. Correction factors are given in function of the length of the rigid arc for a number of span/major axis ratios; also the rigid length required for zero correction is given.

G. Kuerti, USA

4595. **Erdmann, S. F., A new very simple interferometer for obtaining flow pictures for quantitative analysis** (in German), *Nat. LuchtLab. Amsterdam Ber.* F.68 = *Appl. sci. Res.* B2, 3, 149–198, 1951.

Paper describes how interferometric pictures may be obtained with a schlieren arrangement using monochromatic light. The second knife edge is replaced by a narrow interference slit having the central part transparent and the outer part *nearly* opaque. Method is based on phase-contrast principle. Theory is given in detail and examples of application to investigation of supersonic flows are included. A coincidence optical system was used for the experiments. Some of the results are evaluated quantitatively.

Due to inferior optical quality of mirror and tunnel glass walls used, it was not possible to investigate fully the advantages of the method, which may prove to be very valuable. Further development work is needed. N. Holm Johannesen, England

4596. **Gracey, W., Letko, W., and Russell, W. R., Wind-tunnel investigation of a number of total-pressure tubes at high angles of attack,** *Nat. adv. Comm. Aero. tech. Note* 2331, 69 pp., Apr. 1951.

An investigation of fixed total-pressure tubes which will remain insensitive to inclination of the air stream over a wide range of angles of attack. The angle of attack of 39 total-pressure tubes has been determined for an angle-of-attack range of $\pm 45°$ and an indicated air speed of 195 mph. The external shapes tested included cylindrical, conical, and ogival-nose sections. The internal shapes and total-pressures entries were varied on the basis of such factors as size of impact opening, shape of internal chamber, internal bevel, leading edge sharpness, slant profile, and shielding (combined with venting). Design details and pertinent dimensions of each of the tubes is given with their calibration curves at the end of the paper.

A comparison of the calibration curves shows that a shielded total-pressure tube (Kiel type) having a vent area equal to 1.5 times the entrance area is the least sensitive to inclination of any of the tubes tested. The angle-of-attack range over which this tube remained insensitive to within 1% of the impact pressure was $\pm 41.5°$. The remaining calibration curves showed that cylindrical tubes are less sensitive to misalignment than either conical or ogival-nose sections.

From authors' summary by C. Newman, USA

4597. Kaan, J. F., and Westerdijk, J. B., An optical method for following mixing processes (in Dutch), *Ingenieur* **63**, 26, 0.33–0.35, June 1951.

An apparatus is described which indicates the increasing homogeneity of a mixture of fluids or gases during the mixing process. The optical method is very sensitive and allows the operator to observe even very small fluctuations of the concentration.

From authors' summary

4598. Boelter, L. M. K., and Lockhart, R. W., An investigation of aircraft heaters XXXV. Thermocouple conduction error observed in measuring surface temperatures, *Nat. adv. Comm. Aero. tech. Note* 2427, 34 pp., July 1951.

When thermocouples are used to measure the temperature of surfaces which are exposed to fluids at temperatures different from that of the surface, errors occur because of conduction of heat along the thermocouple wires. These errors have been analyzed and predicted in a previous report; the present report presents experimental results which verify this analysis.

The data also indicate that the electrical insulation of the wires is not effective in reducing the errors involved when the thermocouples are placed normal to the surface and exposed to the ambient fluids. The errors are greatly reduced, however, if the wires are maintained in thermal contact with the plate for about 4 inches before allowing the wires to pass through the fluids.

A welding device utilizing the electrical discharge from a bank of condensers was successfully used to attach thermocouples (No. 28 to No. 40 B. & S. gage) to the metallic surfaces.

From authors' summary

4599. Stearns, R. F., Johnson, R. R., Jackson, R. M., and Larson, C. A., Flow measurement with orifice meters, New York, D. Van Nostrand Co., Inc., 1951, xviii + 350 pp. $7.50.

Book has been written mainly for those concerned with control and test work in the petroleum industry. It is an enlargement of previous editions that were used by the Standard Oil Development Company. Because these earlier editions proved valuable, it was decided to make the material available to the engineering profession.

The derivation of the flow equations for liquids and gases is given first, and these equations are then transformed so as to be convenient for computations of the type that are common in the petroleum industry. Sections follow on the application of the flow equations to metering problems, the evaluation of the variable terms in the equation, the principles of operation of commercial meters, the interpretation of meter records, the installation of orifice meters, testing and checking meters, a consideration of special metering problems such as pulsations, and a discussion of accuracy that can be obtained.

There are three appendixes: A, supplemental metering information; B, numerical data which include tables of coefficients, conversion factors, and so on; and C, physical data covering sealing and manometer liquids, specific gravities of liquids, densities of gases, viscosities of liquids and gases, and specific heat ratios for various gases.

The book is excellently documented with a bibliography that contains 71 items. Glen N. Cox, USA

4600. Eujen, E., Measurement of small flow velocities (in German), *Z. Ver. dtsch. Ing.* **93**, 21, 669–674, July 1951.

Brief review of instruments for practical researches on such small fluid velocities that the Pitot tube cannot be applied: mechanical devices (rotating-vane anemometers for air and water, anemometers based on the torque exerted by the fluid on a movable part of the instrument = velo meter) and hot-wire anemometers. Concise description is given of an anemometer consisting of a hot-wire coil mounted in the open end of a kind of Pitot tube and one or more thermocouples in the warm wake of this coil [see E. Eujen, AMR **4**, Rev. 746].

B. G. van der Hegge Zijnen, Holland

4601. Hardway, E. V., Jr., A method for correcting orifice-meter measurements for flow pulsations, *Instruments* **24**, 7, 763–765, 774–775, July 1951.

In natural-gas transmission lines pressure pulsations arise from reciprocating compressors. These rapid pressure changes produce important errors in quantity of flow measurement, since all existing flowmeters are designed and calibrated for steady-state conditions. Most generally the errors do not average out, the measured flow being in excess of the actual flow. Commercially acceptable error tolerances are frequently exceeded, a condition which affects adversely the determination of system leakage and marketing aspects.

Assuming steady-state flow equation holds for pulsating flow, author derives approximate correction for orifice meters having a small ratio of differential pressure to total static line pressure. Method consists in relating the first significant term in the expansion of binomial error function to the average differential head and the root-mean-square of the fluctuating pressure. Formula is tested mathematically for several wave forms and found to give accuracy of 1% flow up to pulsation errors of about 7%. Instrumentation required to employ correction formula is briefly described. John P. Breslin, USA

Thermodynamics

(See also Revs. 4536, 4538, 4541, 4586, 4634)

4602. Stoever, H. J., Engineering thermodynamics, New York, John Wiley & Sons, Inc., May 1951, vii + 458 pp. $5.75.

Intended for a one-year undergraduate course, text is divided into three principal parts: First law, Second law, Applications. Diagrams and schematic sketches are used sparingly but adequately. 507 problems are given, graded as to difficulty. Use of Keenan and Keyes steam tables is required. An abridged ammonia table is included in the appendix. In the early sections important concepts are emphasized by bold face for ease in reviewing the definitions.

Although this is not specifically pointed out, it seems safe to assume that the text was prepared at considerable expenditure of effort and time, to fill a particular need which the author felt for this treatise. It must, furthermore, be assumed that he deepens considerably the understanding of the subject in the student's mind by his personal presentation and additional material.

Reviewer feels that without the author's personal presentation the book leaves much territory untouched. This is presumably justified by the definition of "engineering thermodynamics" given in the introduction as being "characterized by the facts that only work of the mechanical type is considered and only substances that undergo no changes in chemical composition and that are subject to no surface, electric or magnetic effects are considered." Reviewer feels that this restrictive definition is no longer adequate for even moderate requirements of modern engineering. Such grossly simplified treatment leads the student to believe that he now knows all there is to thermodynamics, whereas in reality only cook-book knowledge has been acquired. This feeling is strengthened by the complete absence of references which might shed further light on the subject.

We find, for instance, the following footnote (p. 212): "The difference between the entropies at any two states of a system

can be calculated by means of the so-called Maxwell relations if the p-v-t relation for the system is known." It would be easy enough to quote a reference here which presents more detail on these mysterious relations. Other concepts, such as that of efficiency, are pulled out of a hat without proper foundation being laid.

In some instances more precision could be obtained at no extra cost. There is a difference between an exact differential, e.g., dV, and an inexact differential, e.g., DW. This is not mathematical hair-splitting but sound physics.

Air is said to consist of nitrogen, oxygen, argon, and traces of certain other gases. Why not be specific and quote typical composition? As it stands, one is led to guess that maybe nitrogen and argon are present in similar amounts.

When introducing the Mollier diagram, it would be well to point out that this may mean either an h-s or a p-h diagram, the latter being very useful in working refrigeration problems.

It is gratifying to find vapor-cycle diagrams (T-S plane) in which the isentropic pump work is shown.

The section on refrigeration is good, that on nozzles and turbines adequate.

Chemical thermodynamics is ruled out by command decision.

Peter Kyropoulos, USA

4603. Porter, A. W., Thermodynamics, London, Methuen & Co.; New York, John Wiley & Sons, Inc., Oct. 1951, vii + 124 pp., 21 diagrams. $1.50.

4604. Zeldovich, Y. B., Theory of flame propagation, *Nat. adv. Comm. Aero. tech. Memo.* 1282, 39 pp., June 1951.

Equations are presented for heat conduction and diffusion in a flame, taking into account the chemical reaction. Temperature distribution in the flame, and conditions required for a constant flame velocity are considered. A method is given for determining the flame velocity for a given relation between diffusion and heat conduction by numerical integration, and its uniqueness is demonstrated. Equations are also given for flame propagation in a chain reaction.

From author's summary by Anthony W. Jones, USA

4605. Schmidt, E., Steinicke, H., and Neubert, U., Flame and schlieren photographs of the combustion of gas-air mixtures in tubes (in German), *VDI-Forschungsheft* **431,** 31 pp., 1951.

Combustion of air-propane mixtures in tubes of about 1 in. square and 1-yd length is investigated by means of photographs of the light of the flame and by schlieren pictures under different test conditions (open and closed tube, different initial pressure, air content, oxygen content). Pictures show entire cross section; spark frequency for schlieren pictures between 1000 and 24,000 per sec. Many details are shown, especially those arising from turbulence with ensuing change of form of flame head and increase in flame velocity. Mixtures with increased oxygen content give compressions and shocks in front of flame. With oxygen content increased to about twice the normal amount, one obtains transition to detonation.

From authors' summary by Gottfried Guderley, USA

4606. Fenn, J. B., Forney, H. B., and Garmon, R. C., Burners for supersonic ram-jets. Instability in a two-inch ram-jet burner, *Indust. Engng. Chem.* **43,** 7, 1663–1672, July 1951.

Last work, mostly of qualitative nature, by the authors and other workers is described. A large body of experimental data taken on a two-inch ramjet burner in which the following parameters were varied is presented: 2 igniters—0.75-in. cone with and without radial gutters; 2 tail-pipe lengths—14 and 18 in.; 2 humidities—0.01 and 0.25 lb water per lb dry air; 3 fuel injectors—each composed of 8 injection needles terminating in annular orifices, orifice size varied.

Results are classified according to frequency range of instability: Class A (20–30 cps) is associated with a coupling between the fuel-injection system and burner. Eliminated by constant-rate (high-pressure) fuel injection. Class B (35–60 cps) is characterized by detonation upstream of igniter and is due to poor ignitions, being obtained only with simple cone igniters. Boundary-layer injection of water and some salt solutions were found to be effective in reducing this instability. Class C (100–130 cps) is function of geometry of duct system and is interpreted in terms of fundamental frequency associated with duct length.

K. R. Wadleigh, USA

4607. Matz, W., Thermodynamics of heat and mass transfer in process technique [Die Thermodynamik des Wärme- und Stoffaustauches in der Verfahrenstechnik], Frankfurt M., Dietrich Steinkopff, 1949, 355 pp., 114 figs.

This represents a basic text comparable to many identified as chemical engineering thermodynamics. The thermodynamic formulation and equilibrium consideration form the basis for the larger part of the treatment. The first chapter presents a general survey of thermodynamic principles with particular reference to the energy functions relevant to equilibrium. The dimensionless parameters occurring in heat and mass transfer are introduced. The second chapter considers heat and mass transfer between two phases by various mechanisms. The similarity laws for transfer processes are described. Chapter three considers heat and mass transfer between vapor and liquid phases with particular reference to vaporization and to air-vapor mixtures. The remaining chapters are devoted to distillation, adsorption, absorption, and extraction, respectively. In each case the thermodynamic fundamentals relevant to process mechanism, description, and equilibrium together with a survey of the use in industry and process operations are given. The level is such that this material would be of greatest value to the practicing chemical engineer and not to research.

Newman A. Hall, USA

4608. Longuet-Higgins, H. C., The statistical thermodynamics of multicomponent systems, *Proc. roy. Soc. Lond. Ser. A,* **205,** 1081, 247–269, Feb. 1951.

The author treats the equilibrium of gas or liquid mixtures in the special case when all the molecules are, in a certain specific sense, nearly alike. In return for this limitation he is able to proceed without assuming any type of lattice structure and with fewer mathematical inaccuracies than is customary in this subject. The special type of solution is defined by the following properties: The mutual potential energy of two molecules of species L_r and L_s at a distance ρ is $f_{rs}u(g_{rs}\rho)$, where f_{rs} and g_{rs} are constants close to 1, and $2g_{rs} = g_{rr} + g_{ss}$. The author shows that, correct to the first order in the quantities $f - 1$ and $g - 1$, the Gibbs free energy G of the solution is given by $G = \Sigma x_r(G_r + RT \log x_r) + E_0\Sigma x_r x_s E_0 dr s$, where G_r is the free energy and x_r the mole fraction of the species L_r, E_0 is the configurational energy of any one of the species, and $d_{rs} = 2f_{rs} - f_{rr} - f_{ss}$. Hence he calculates two forms of thermal equation of state and shows that the reduced equation of state for the mixture is the same as that for any component. He calculates the excess entropies and volume changes of mixing for liquid solutions, finding rather good experimental confirmation for a large variety of cases. The paper is distinguished by unusual care in the statement of the assumptions and the use made of them.

C. Truesdell, USA

4609. Tordai, L., Errors in diffusion measurements by the Loschmidt method, *Brit. J. app. Phys.* **1,** 12, 329–332, Dec. 1950.

Paper discusses precise methods of measuring diffusion coefficients of gases by means of classical method of Loschmidt. Method consists of connecting identical tubes of gases for a measured time interval and analyzing for the resultant gas-mixture compositions in the tubes. Diffusion coefficients can be calculated by using data on the change in gas composition with time.

Author uses equation for one-dimensional interdiffusion of perfect gases to develop formula for the diffusion coefficient as calculated from Loschmidt-method data. Correction factors are developed to compensate for small errors inherent in the method. Typical errors corrected for are differences in the volume of the half tubes, small pressure differences in the two half tubes when they are initially joined, and the finite times required to join and separate the half tubes. Methods of calculating the junction-time intervals and concentration ratios that will give the most accurate data are developed. Data values of the error contribution of the second-order effects and the accuracy of the compensated equation are presented. Thomas P. Clark, USA

4610. Babbitt, J. D., On the differential equations of diffusion, *Canad. J. Res. Sec. A*, **28,** 449–474, 1950.

In this paper the equation governing the diffusion of gases through media in which adsorption of the diffusing gas takes place is considered. If N denotes the number of adsorbed molecules per unit volume, $\mathbf{u}$ the rate of flow and ϕ the so-called spreading pressure, the equation of continuity, div $(N\mathbf{u}) = -\partial N/\partial t$, combined with the law $\mathbf{u} = -\gamma$ grad ϕ (γ = a constant) gives γ div (N grad ϕ) $= \partial N/\partial t$. Combining with the adsorption isotherm which provides a relation of the form $\phi = f(N)$, we get γ div (N grad $f(N)$) $= \partial N/\partial t$. By discussing the stationary case when N grad $f(N)$ should be a constant, author concludes that the available body of experimental evidence supports his form of the diffusion equation.

S. Chandrasekhar, USA

4611. Carman, P. C., Diffusion and flow of gases and vapours through micropores, I. Slip flow and molecular streaming, *Proc. roy. Soc. Lond. Ser. A*, **203,** 1072, 55–74, Sept. 1950.

Author presents experimental and theoretical studies on "slip flow." Many writers have observed that viscous flow will undergo a transition to slip flow when the pore diameters become comparable with the molecular mean free path of the gas. For flow in circular capillaries, Knudsen (1909) pointed out that, when molecular mean free paths are of the same order as capillary diameter, the plot GL/A against p is no longer linear, but passes through a minimum and then approaches the limiting value for molecular flow at very low pressures ($G = p_1/\Delta p \cdot t$, where Δp is the pressure drop in the capillary, and t is time).

Author demonstrates that this slight minimum found by Knudson in the G-p plot is greatly exaggerated for noncircular cross sections. An approximate theory is used for calculations on the noncircular cross section by using the concept of a mean hydraulic radius.

Author raises the interesting question whether a similar minimum in the G-p plot might be expected in a pore system of porous medium. By a series of elaborate experiments, he establishes that, while the plot of G vs. p sometimes undergoes a small change of gradient in the transition region, no sign of a minimum is detected. Results indicate that, for all practical purposes, it is sufficient to assume that the plot G against p is linear for all values of p. By using a number of powders of different particle size and four different gases, a wide range of d_e/τ was covered (τ is molecular mean free path, and d_e is a dimension of length analogous to pore radius). J. S. Aronofsky, USA

4612. Carman, P. C., and Malherbe, P. leR., Diffusion and flow of gases through micropores, II. Surface flow, *Proc. roy. Soc. Lond. Ser. A*, **203,** 1073, 165–178, Sept. 1950.

Flow through porous plugs has been measured under conditions where surface flow of adsorbed gases makes an important contribution. An analysis of variables affecting surface flow enables surface-diffusion coefficients to be calculated and has indicated conditions likely to reduce the correction for flow in the gaseous phase to small proportions. This has been confirmed by studying the effect of variations of porosity.

Surface-diffusion coefficients tend to increase with "coverage" of the adsorbent surface. This requires further study.

Activation energies measured for one system were found to be rather small. Owing to the variation of surface-diffusion coefficients with coverage, it proved difficult to obtain accurate values. Activation energies indicated a tendency to decrease as coverage increases. Further experiments on these points are also being carried out.

From author's summary by J. S. Aronofsky, USA

4613. Stalder, J. R., and Zurick, V. J., Theoretical aerodynamic characteristics of bodies in a free-molecule flow field, *Nat. adv. Comm. Aero. tech. Note* 2423, 40 pp., July 1951.

An analytic investigation is made of the aerodynamic coefficients of various bodies located in a free-molecule-flow field. These bodies are the following: flat plate, cylinder, sphere, and cone. Calculations are performed using values of molecular speed ratio (ratio of stream speed to most probable molecular speed) ranging from 0 to 20. The calculations are performed assuming two types of molecular reflection, specular and diffuse; in addition, for the cone, a third type of molecular reflection, wherein impinging molecules are not re-emitted from the body but are swept along its surface, is postulated in order to compare the drag coefficients calculated by free-molecule-flow theory with values obtained from continuum theory.

The lift-drag ratios of a flat plate in free-molecule flow are very small for the case of diffuse molecular reflection. The lift-drag ratios decrease as the molecular speed ratio is increased. For case of diffuse molecular reflection, the lift and drag coefficients of all bodies investigated approach constant limiting values at high speeds. At low speeds, the drag coefficients for all the bodies approach an infinite value; this is due to the fact that the drag force is proportional to the first power of the velocity at low speeds. For the case of specular reflection, the aerodynamic coefficients of all the bodies investigated likewise approach constant limiting values at high speeds.

From authors' summary by F. K. Hill, USA

Heat and Mass Transfer

(See also Revs. 4494, 4496, 4553, 4598, 4607, 4670)

4614. Robb, W. L., and Drickamer, H. G., Transport properties of dense media. I. Thermal diffusion in isotopic mixtures of gases, *J. chem. Phys.* **18,** 10, 1380–1382, Oct. 1950.

Based on Meixner's thermodynamics for irreversible processes, and the work of Haase, an equation for the thermal diffusion ratio α, which can be evaluated from the equation of state, is presented. Using van der Waals' equation, α's are calculated in the critical region and compared with data for ethane-xenon. The equation reproduces all the essential features of the experimental results. Calculations made for a mixture of isotopes indicate that

the effect of pressure on α cannot be attributed to selective clustering.

From authors' summary by Warren M. Rohsenow, USA

4615. **Weiner, J. H., Gross, D., and Paschkis, V., An experimental determination of local boundary conductances for an unbaffled circular-finned cylinder,** Gener. discuss. heat transfer, Lond. Conf., Sept. 11–13, 1951, Sec. II, London, Instn. mech. Engrs.; New York, Amer. Soc. mech. Engrs., 6 pp., 1951.

Experimental data are presented for the point-to-point variations in unit thermal conductance between the fins of an unbaffled circular-finned cylinder and a water stream in the range of Reynolds modulus 8150 to 35,900. Myron Tribus, USA

4616. **Broughton, G., Glass mat surfaces as radiant heaters, their use in ovens and driers,** Gener. discuss. heat transfer, Lond. Conf., Sept. 11–13, 1951, Sec. IV, London, Instn. mech. Engrs.; New York, Amer. Soc. mech. Engrs., 4 pp., 1951.

Interlaced, electrically heated, nichrome wires are threaded through glass-fabric tubing. Back of heater is insulated with glass wool; the front is covered with glass cloth, which attains a uniform temperature controllable between 200 and 700 F. Temperature and moisture content of specimens suspended between two such mat heaters were measured as functions of time. Air could be blown parallel to or through (perpendicularly to) the mats; air velocity was varied between 0 and 30 fpm. Results agree with known data on other radiant heaters. The same rates of drying were found for various materials. At low mat temperatures total costs decrease by blowing air through the mats.

H. A. Vreedenberg, Holland

4617. **Kayan, C. F., Heat exchanger analysis by electrical analogy studies,** Gener. discuss. heat transfer, Lond. Conf., Sept. 11–13, 1951, Sec. III, London, Instn. Mech. Engrs.; New York, Amer. Soc. mech. Engrs., 5 pp., 1951.

An electrical analog is developed for fluid-to-fluid heat exchangers. The reciprocal of the product of flow rate by specific heat for each stream is considered a thermal resistance to temperature change of the stream. The heat exchanger is divided into sections, each being represented by three electrical resistors in series, proportional to the temperature-change resistance of one stream, the over-all heat-transfer resistance, and the temperature-change resistance of the other stream. These series circuits are connected in parallel, and the total heat transfer is obtained from the total current. Variations in properties and coefficients can be introduced by trial and error. A case of counterflow is worked out in five sections. C. F. Bonilla, USA

4618. **Bošnjaković, F., Calculation of heat exchangers** (in German), *Schweiz. Bauztg.* 69, 24, 27; 332–334, 375–378; June, July 1951.

Under certain simplifying assumptions, the (dimensionless) mean temperature difference, as a function of the (dimensionless) temperature changes of the two heat-exchanging fluids, is widely adopted for characterizing heat exchangers of different types. Author derives and suggests the use of another set of dimensionless variables which does not reflect the exclusive influence of the temperature fields, but emphasizes some of the technical and operational aspects of the apparatus. Diagrams are given for some simple heat-exchanger types, which are the results of simple coordinate transformations as compared with the more usual forms of presentation. Examples are outlined, illustrating the application of such diagrams to typical technical problems in heat-exchanger design, including studies in design for maximum economy. General conclusions are derived for the operational characteristics of groups of heat exchangers, being arranged in different ways in series or parallel. The article is an extract from a more elaborate publication by the same author, "Einheitliche Berechnung der Rekuperation," which will appear as a *VDI-Forschungsheft.* H. H. Korst, USA

4619. **Eckert, E. R. G., and Low, G. M., Temperature distribution in internally heated walls of heat exchangers with noncircular flow passages using coolants with very low Prandtl number,** *Nat. adv. Comm. Aero. tech. Note* 2401, 29 pp., July 1951.

Author assumes low Pr, fully developed flow patterns as determined by Nikuradse, constant properties of coolant, uniform heat generation in the walls, thickness of passages small compared with hydraulic diameter thus neglecting heat conduction within walls, no free convection effects nor internal friction of fluid. With reduced heat equation resulting from these assumptions and equation of heat generated by walls, author solves equations numerically by relaxation method. The boundary condition is that all heat generated by internal heat sources within the passage walls must, in steady state, be transferred into the coolant. Author solves equations of heat transfer for heat exchangers with triangular and rectangular passages.

Appendix covers tentative solutions of temperature distribution in circular tubes and between two parallel infinite plates.

S. Eskinazi, USA

4620. **Casci, C., On the distribution of temperature in a ring in steady state placed in a conduit traversed by gas flows with different temperatures** (in Italian), *Atti Accad. Naz. Lincei Rend. Cl. Sci. Fis. Mat. Nat.* (8) 9, 3–4, 163–169, Sept.-Oct. 1950.

One-dimensional analytic solution is presented for temperature distribution in continuous metallic ring, subject to heating by fluid on one half of its peripheral surface and cooled by second fluid on remaining half. M. J. Goglia, USA

4621. **Kutateladze, S. S., Hydrodynamic theory of change of the boiling of a liquid at free convection** (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk*, no. 4, 529–536, Apr. 1951.

Author deals with boiling under pressure. Using dimensional analysis, it is concluded that $r \cdot (g\gamma)^{1/2}\sigma^{1/4}(\gamma - \gamma'')^{1/4}/q$ should be constant, independent of the boiling pressure (r latent heat of boiling; g gravitational acceleration; γ, γ'' specific densities of the liquid and the vapor; σ surface tension; q heat flow at boiling). It is shown that this happens to be the case for various liquids over a wide pressure range. Secondly, it is shown that if boiling occurs while there exists a temperature difference ϑ between vapor and liquid, the heat flow q will be given by the equation $q = q_0[1 + (1 - n)c\gamma\vartheta/r\gamma'']$ (there is a misprint in this equation in the original), n recirculation coefficient; c specific heat of the liquid. This relation is shown to be obeyed by alcohol ($p = 1 - 10$ atm, $c\vartheta/r$ up to 0.8), isooctane ($p = 1$ atm, $c\vartheta/r$ up to 0.5) and water ($p = 1$ atm, $c\vartheta/r$ up to 0.15).

D. ter Haar, Scotland

4622. **Charles, H., On the heat equation in the theory of heredity** (in French), *Bull. Soc. roy. Sci. Liège* 20, 5, 374–377, May 1951.

The integrodifferential equation

$$U_t(x, t) - U_{xx}(x, t) = {}_0\int^t K(t - r)U_{xx}(x, r)\, dr$$

arising in the theory of heat conduction, is investigated by use of the Laplace transform. Explicit formulation is indicated for several types of kernel K.

Newman A. Hall, USA

4623. Vallander, S. V., and Elovskikh, M. P., Theoretical dependence of coefficient of heat conduction of gases on temperature (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **79**, 1, 37–40, July 1951.

By considering the flow of heat between concentric cylinders at different temperatures in a gas satisfying the equations derived in a previous paper [see Rev. 4538 in this issue], the first author derives the law of temperature dependence of the heat-conduction coefficient as

$$k = c_v(\beta_2 - \beta_1)\,\tau_1 \int^{T_2} \mu dT/(T_2 - T_1)$$

where $\beta_{1,2}$ are constants, and $T_{1,2}$ are the temperatures of the cylinders; when the temperature jump is small, this becomes the usual formula. Leon Trilling, USA

4624. Sestini, G., On two problems of heat conduction in a heterogeneous body with cylindrical symmetry (in Italian), *Riv. Mat. Univ. Parma* **1**, 405–417, 1950.

In earlier papers [*Ist. Lombardo Sci. Lett. Cl. Sci. Mat. Nat. Rend.* (3) **6(75)**, 47–65, 1942; *Univ. Roma. Ist. Naz. Alta Mat. Rend. Mat. e appl.* (5) **6**, 464–477, 1947] author stated two boundary-value problems on the conduction of heat in coaxial cylinders for the differential equation (*) $U_{rr} + U_r/r = U_t$, but carried out his analysis for the equation $U_{rr} = U_t$. In the present paper his stated problems are solved for the desired equation (*).

Courtesy of Mathematical Reviews F. G. Dressel, USA

4625. Kays, W. M., and London, A. L., Remarks on the behavior and application of compact high-performance heat transfer surfaces, Gener. discuss. heat transfer, Lond. Conf., Sept. 11–13, 1951, Sec. II, London, Inst. mech. Engrs.; New York, Amer. Soc. mech. Engrs., 6 pp., 1951.

An accumulation of convective heat-transfer and flow-friction design data for 34 different configurations of compact heat-transfer surfaces has been analyzed to obtain information adequate for design purpose. Nondimensional coefficients of heat transfer and friction power are used instead of the conventional dimensional quantities for comparison of the merits of the geometry of the surfaces. The over-all flow friction is analyzed in terms of form drag and skin friction. A short discussion of transition flow behavior for duct-type surfaces is also given. S. I. Pai, USA

4626. Anthony, M. L., Temperature distributions in composite slabs due to a suddenly activated plane heat source, Gener. discuss. heat transfer, Lond. Conf., Sept. 11–13, 1951. Sect. III, London, Instn. mech. Engrs.; New York, Amer. Soc. mech. Engrs., 14 pp., 1951.

Author gives formulas for temperature T as a function of time t and location x for number of one-dimensional heat-conduction problems, in which $T = 0$ for $t < 0$ and, starting at the time $t = 0$, a plane heater H supplies heat with constant flux.

Solutions, obtained by Laplace transform method, are given for the following cases: I | aHbc | I; I | aHbc | C; I | aHbc | T; C | aHbc | I; C | aHbc | C; C | aHbc | T; T | aHbc | I; T | aHbc | C; T | aHbc | T, and the cases derived from it for $a = 0$, $b = c$, or both. Herein a, b, and c are the thicknesses of three slabs with thermal properties independent of T, t, and x and in perfect thermal contact at each interface; the vertical line represents the wall; I is wall isolated, T wall at constant temperature $T = 0$, C convection to a medium with $T = 0$; H gives the position of the heater. All 27 solutions contain sums extended over the positive roots of a trigonometrical equation.

Furthermore, solutions in terms of tabulated functions are given for the following six cases with one or two of the slabs infinitely thick: I | Hab; I | aHb; T | aHb; aHb; I | Ha; C | Ha.

H. Wijker, Holland

4627. Rubinshteĭn, L. I., On heat conduction in a multilayer medium with phase transitions (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **79**, 2, 221–224, July 1951.

Author considers a multilayer system consisting of one component in an arbitrary number of phases, and obtains the differential equations and boundary conditions governing the one-dimensional conduction of heat and the associated movement of the phase boundaries. A procedure for solution is outlined: It depends on a method given in an earlier paper [*Dokaldi Akad. Nauk SSSR* **58**, no. 2, 1947]. Reviewer notes that author's equations do not account explicitly for the fixed values of the temperature at the phase boundaries, so that his solution cannot be accepted unreservedly. R. Eisenschitz, England

4628. Allen, D. N. de G., and Severn, R. T., The application of relaxation methods to the solution of nonelliptic partial differential equations. I. The heat-conduction equation, *Quart. J. Mech. appl. Math.* **4**, part 2, 209–222, June 1951.

Aim of the paper is to bring the heat-conduction equation within the scope of relaxation methods. The difference between "jury" and "marching" problems—a difference in the prescribed boundary conditions—is stated. Application of the relaxation method to other than elliptical differential equations is explained by a simple, one-dimensional example. The solution procedures of the equations $v_{xx} = f(x)$ and $v_x = x + v$ are indicated. Finally, the two-dimensional heat-conduction equation $v_t = kv_{xx}$ is solved by the relaxation method. Paul Torda, USA

4629. Farber, E. A., Investigation of steam separation in boiler drums through studies on a model, *Trans. Amer. Soc. mech. Engrs.* **73**, 3, 247–256, Apr. 1951.

An experimental study of the effect of steam-boiler-drum internals on "carry-over" of moisture into vapor tubes and "entrainment" of vapor in the downcomer tubes is made in a scale model of boiler drum. The density ratio of liquid to vapor in model is made equal to that of water in prototype by using Freon 12 in equilibrium with its own vapor. The separation forces are made equal in the model and prototype by adjusting velocities in the model.

Author finds reasonable correlation between model and prototype for carry-over, but correlation is not as good in case of entrainment. Model tests give good qualitative results and make possible a comparison of different boiler internals.

Reviewer believes use of Freon 12 is a valuable contribution toward the laboratory duplication of mixture densities, velocities, and separating forces in a boiler drum.

William A. Wolfe, Canada

4630. Berman, R., The thermal conductivity of some alloys at low temperatures, *Phil. Mag.* (7), **42**, 329, 642–650, June 1951.

The thermal conductivities of German silver, stainless steel, and Constantan have been determined between 2 and 90 K and the electronic and lattice components of the conductivity have been calculated. The electronic conductivity is limited by scattering by "impurities." The lattice conductivity is limited by scattering of the lattice waves by electrons at the lower temperatures and by "impurities" at higher temperatures.

A table is given showing the heat flow along specimens of each alloy resulting from temperature differences commonly met with in practice in low-temperature work.

From author's summary

4631. Traustel, S., Thermal conductivity of gases at high temperatures (in German), *Brennstoff-Wärme-Kraft* **3**, 4, p. 123, Apr. 1951.

This discussion describes briefly the experimental results of Vargaftik on the thermal conductivity of various combustible gases: carbon dioxide, air, nitrogen, oxygen, hydrogen, argon, steam, and binary gas mixtures. The degree of measuring error is estimated at approximately 1 to 2%. G. A. Hawkins, USA

4632. Weininger, J. L., and Schneider, W. G., Thermal conductivity of granular beds filled with compressed gases, *Indust. Engng. Chem.* **43**, 5, 1229–1233, May 1951.

Paper presents information on measurements of thermal conductivity on granular beds of aluminum oxide and powdered borosilicate glass when filled with helium, hydrogen, nitrogen, or carbon dioxide. Measurements were made at pressures up to 100 atm. Within the accuracy of the measurements, conductivity was linear with pressure for all gases except carbon dioxide, which gave a parabolic relationship with pressure. Absorption of gas by the bed was shown to have an appreciable effect on the measured conductivity.

Conclusion was reached that the method used for measuring the pressure coefficient of the thermal conductivity of gases is not particularly satisfactory and has a rather limited application. However, the method may find useful application in the measurement of thermal conductivity of liquids.

F. D. Grossman, USA

4633. Gilmour, A., Solution of certain unsteady heat flow problems by relaxation methods, *Brit. J. appl. Phys.* **2**, 7, 199–204, July 1951.

Transient heat-flow problems involving only one space dimension are dealt with using two-dimensional time-space relaxation net for which appropriate relaxation patterns are derived. Method is demonstrated by application to three problems of heat transfer through walls of highly insulated containers used for transporting frozen produce which requires low storage temperatures. Various boundary conditions are considered.

A. H. Žaludová, Czechoslovakia

4634. Plewes, A. C., and Klassen, J., A study of mass transfer rates from the solid to the gas phase, *Canad. J. Technol.* **29**, 7, 322–331, July 1951.

Pure liquid benzene, and pure solid cyclohexane, phenol, camphor, benzene, and p-dichlorobenzene were evaporated from flat stationary surfaces into an air stream flowing parallel to the surface at atmospheric pressure and from 0 C to 35 C. The diffusional resistance lay wholly within the gas phase. Rates of evaporation could be correlated by the dimensionless Sherwood-Gilliland equation for wetted-wall, liquid-gas, countercurrent contact, $d/x = 0.023\,Re^{0.83}Sc^{0.44}$ (d is equivalent diameter, x effective film thickness, Re Reynolds number, Sc Schmidt number) for Re = 8000 to 30,000 for the liquid and 5000 to 40,000 for the solids. For the liquid, Re above 30,000 caused disturbance of the surface. Robert E. Treybal, USA

4635. Jellinghaus, W., An automatic system for registering heat content curves and for thermic analysis with low heating velocity (in German), *Arch. Eisenhüttenw.* **22**, 1/2, 65–71, Jan./Feb. 1951.

A test procedure of the type first used by C. Sykes to obtain the enthalpy-temperature curve for metals or alloys is described. The probe, with the shape of a cylinder (10-mm diam, 50-mm length), is heated electrically with a coil in the hollow interior of the probe inside a container whose temperature is increased at the same rate as the probe. A thermoelement measures the temperature difference between probe and container. The indicating galvanometer actuates an automatic control system over a photocell and keeps the temperature difference below 1 C. Heat losses from the probe are thus effectively eliminated and the electric heat input into the probe serves solely to increase its enthalpy. The temperature increase of the probe was 0.7 to 2.8 C per min providing sufficient time for the completion of chemical reactions within the material. With the use of a wattmeter a system was designed which recorded the enthalpy-temperature curve automatically. Samples of such curves for alloyed steel are presented. E. R. G. Eckert, USA

4636. McConnell, D., and Earley, J. W., Apparatus for differential thermal analysis, *J. Amer. ceram. Soc.* **34**, 6, 183–187, June 1951.

Information is furnished on newly designed, automatic, recording equipment which has been combined with temperature-control apparatus, Pt-Pt-10% Rh thermocouples, a Globar furnace, and a newly designed sample holder, for the simultaneous production of three thermograms (differential thermal analysis curves). The recording apparatus has several advantages: (1) High sensitivity is obtained by a vacuum-tube amplifier rather than by high-sensitivity galvanometers with special mountings; (2) the thermograms can be examined during the run because photographic processing is not required for development of the record; (3) a special selector switch is employed in conjunction with a single amplifier and a multiple-point recorder, thus eliminating the multiplicity of instruments which would otherwise be required in order to obtain adequate magnification. Platinum-type thermocouples are desirable for several reasons. The apparatus described can be employed safely for temperatures up to 1100 C, above which it would be advisable to use a platinum sample holder rather than one made from Inconel. Complex interrelationships exist between the recording and the control circuits because of the existence of numerous sorts of heat transfer. These factors are briefly discussed in conjunction with their influence on the production of good reproducible thermograms.

From authors' summary

Acoustics

4637. Lambert, J. D., and Rowlinson, J. S., Ultrasonic dispersion in organic vapours, *Proc. roy. Soc. Lond. Ser. A*, **204**, 1078, 424–434, Dec. 1950.

Measurements are made on ultrasonic propagation velocities, at various frequencies and pressures, in several organic vapors. Purpose is to correlate ease of interconversion of translational and vibrational energies, as well as of different modes of vibrational energy (both as evidenced by velocity dispersion), with complexity of molecular structure.

Experimental procedure is based on use of an acoustic interferometer with provisions made for altering gas pressure and temperature. Imperfect gas corrections for ultrasonic velocity and apparent heat capacity are applied by extrapolations to zero pressure. Effects of dimerization are investigated for some cases.

Analysis of results in terms of relaxation times and known molecular vibration frequencies lead authors to conclusion that, except in case of small or rigid molecules with no low vibrational frequencies, polyatomic molecules in general allow, with comparative ease, interconversion of translational and vibrational energies as well as interconversion of vibrational energy between different modes. Paul Tamarkin, USA

4638. Litovitz, T. A., Ultrasonic absorption of glycerin in the liquid and vitreous state, *J. acoust. Soc. Amer.* **23,** 1, 75–79, Jan. 1951.

Molecules of viscous liquid subjected to a high-frequency sound wave cannot instantly adjust to the rapid pressure variations of the wave. The instantaneous molecular configuration lags behind the equilibrium one, but tends toward it exponentially with time. If the relaxation time τ for this process is either very small or very large compared with the period of the sound wave, the energy absorption will be less than at intermediate values of τ. Since $\tau = \tau_0 \exp(E/RT)$, where E is activation energy for the molecular adjustment involved, a plot of absorption coefficient α vs. temperature T will show a peak. If two or more kinds of molecular adjustment occur, each will have its own relaxation time, hence its own characteristic peak.

Author has measured the absorption of 31-mc sound in glycerin over a temperature range from −25 C to 40 C, using a pulse technique. The experiments show a single peak in the α vs. T curve, agreeing with the theory, which predicts the same value of τ for both the shearing and dilatational adjustments involved.

Author has also evaluated τ_0, using both high- and low-temperature data for this purpose. Reviewer has checked this result in a different way, using only the author's high-temperature data and the fact that the const C defined in the paper is proportional to τ_0 (not to τ_0^2, as given in the paper).

B. G. Rightmire, USA

4639. Vigoureux, P., Ultrasonics, New York, John Wiley & Sons, Inc., June 1951, vi + 163 pp. $4.

A short, but clear and concise account of the generation, propagation, and detection of ultrasound in fluids, together with the simpler aspects of the theory. Solids are not treated. No account is given of recent work in monatomic gases and shear waves in liquids. The radiation-resistance method and the double-crystal interferometer are not discussed; hot-wire techniques are only mentioned. A bibliography brings that of Bergmann up to date. The illustrations and typography are very good. Book furnishes an excellent introduction to ultrasonics for the nonspecialist and should be useful to the physicist in the same way that Carlin's book is useful to the engineer.

Martin Greenspan, USA

4640. Ingard, U., On the reflection of a spherical sound wave from an infinite plane, *J. acoust. Soc. Amer.* **23,** 3, 329–335, May 1951.

Author treats reflection of spherical waves from infinite plane assuming a normal impedance β independent of angle of incidence. Mathematical method employed is based on Weyl [*Ann. Phys.*, **60**, 481, 1919], representing the spherically symmetrical potential $\exp(ikr)/kr$ in terms of plane waves with real and imaginary angles of incidence.

Author expresses pressure in reflected wave as a definite integral in terms of an image source of strength Q. This Q is evaluated in the special case of "matching" $\beta = 1$ or normal incidence $\theta_0 = 0$, by identification of the integral with well-known Laplace transforms. Reviewer notes that Q is the Laplace transform of $<R(t)>\Delta v$, defined in Eq. (6). Unfortunately, the general case Eq. (10) cannot be identified with any well-known transform. By making an approximation in the integral for Q, author develops a method for the general case β complex and $\theta_0 \neq 0$. In calculating the function F, a negative sign has been omitted from Eqs. (12) and (14). This changes the sign of arg F in Figs. 2 and 4; F is unchanged. In Eq. (13) there is a slip in converting the Whittaker function W into an error function: result given in terms of the error function appears to be correct. Pressure contours are given for certain cases with β real, illustrating the effect of the hardness of the wall. Paper concludes with a discussion of the application of results to the measurement of acoustic impedance.

J. M. Jackson, Scotland

4641. Zmuda, A. J., Dispersion of velocity and anomalous absorption of ultrasonics in nitrogen, *J. acoust. Soc. Amer.* **23,** 4, 472–477, July 1951.

Author presents results of his measurements of velocity and absorption of ultrasonic waves in nitrogen. He used an interferometer of the variable path type developed by Hubbard.

The frequency of the waves was 2.992 mc/sec and the pressure range in the gas was 2.09 to 76 cm of Hg at a temperature of 29 C. A velocity dispersion was found ranging from 354.3 to 364.4 m/sec. The ratio of the experimental to the classical absorption, $\alpha_{exp}/\alpha_{class}$, dropped from 1.40 to 1.32, and the corresponding value of Cv/R dropped from 2.50 to 2.08.

Theoretical values for the change in velocity and in the absorption ratio, calculated by applying the equations for the exchange of energy between translational and *vibrational* degrees of freedom, show good agreement with the observed values, although the increase in velocity and the decrease in $\alpha_{exp}/\alpha_{class}$ is interpreted as due to the slow exchange of energy between the translational and *rotational* degrees of freedom. The relaxation time for rotation was found to be 1.2×10^{-9} second.

W. H. Pielemeier, USA

4642. Westervelt, P. J., The theory of steady forces caused by sound waves, *J. acoust. Soc. Amer.* **23,** 3, 312–315, May 1951.

Starting from Eckart's equation for the conservation of acoustic momentum and from Brillouin's radiation stress tensor, author derives a general formula for the forces due to radiation pressure arising from the interaction of a collimated beam of sound with an object. The derived expression is valid for objects of any shape having an arbitrary nonuniform boundary impedance. A complex drag coefficient is defined with the real part representing the component of the force per unit projected area lying in the direction of the incident momentum and the imaginary part representing the normal component. Furthermore, author investigates for a rigid sphere the modification of the radiation force due to the nonlinear properties of the fluid, especially the viscous losses in the boundary layer. Finally, the influence of asymmetry in the particle-velocity wave form is discussed with the hint (perhaps to be published in a later paper) that this asymmetry causes, under certain circumstances, forces of some orders of magnitude greater than those due to radiation pressure.

Karl Pohlhausen, USA

4643. Fay, R. D., and Fortier, O. V., Transmission of sound through steel plates in mersed in water, *J. acoust. Soc. Amer.* **23,** 3, 339–346, May 1951.

Very extensive data of transmissivity as a function of angle of incidence and frequency-plate thickness product are presented. Authors' intention is to find tractable modifications for finite plates of infinite area plate theory. They do not feel that lack of agreement with theory can be attributed in all cases to dissipation losses, as do other authors [AMR **4**, Rev. 2827].

Standard pulse techniques are used, and results are presented graphically on a convenient three-dimensional surface. The frequency-thickness range from 0 to 1000 kc-in. was studied. Classical theory gives twenty-six curves of maximum transmissivity in this region, which are compared with data. There are systematic discrepancies in some regions. An analysis for plates of finite size is presented and some special cases considered. While not conclusive, indications are that observed anomalies

are explicable on this basis. Authors feel that ideal conditions for transmission never actually exist because the impinging sound is not a strictly plane-wave motion. Their analysis suggests a secondary wave system originating at the edges of the plate which may exist to some degree in all cases. This system affects the divergence of the beam and also reduces the transmission.

Donald G. Ivey, Canada

4644. Levine, H., The wave length of a spherical resonator with a circular aperture, *J. acoust. Soc. Amer.* **23,** 3, 307–311, May 1951.

The space-dependent part of the velocity potential inside or outside the sphere can be calculated as a solution of Poisson's equation when the velocity distribution over the aperture is assumed. Using Green's functions, the velocity potential on both sides of the aperture can be found. Equating these, an integral equation is found, from which the resonance frequencies and associated velocity distributions in the aperture can be calculated. An approximate solution is found when a velocity distribution in the aperture is estimated and the integral of the difference of the velocity potentials over the aperture is equated to zero. This gives an equation from which an approximation of the resonance frequency or wave length can be calculated. Article gives an extension and slight improvement of the work of Lord Rayleigh [*Proc. roy. Soc. Lond. Ser. A*, **92,** p. 265, 1916] and F. P. White [same source, p. 549] on this problem.

W. H. Muller, Holland

4645. Eckhart, G., Acoustic characteristics of the atmosphere (in French), *Rech. aéro.* no. 21, 59–66, May-June 1951.

Author considers the properties of a stratified atmosphere, i.e., one whose pressure, temperature, and relative humidity are functions only of the height above the surface of the earth. The major portion of the paper is devoted to statements, formulas, graphs, and tables showing the effects of temperature and relative humidity on the velocity, characteristic impedance, and attenuation of sound waves in air. It is a useful summary of this information.

Author also presents information on the effects of temperature and humidity on the propagation of electromagnetic waves. He points out that whereas changes in temperature are much more significant than changes in humidity with regard to sound propagation, the reverse is true in the electromagnetic case. Author suggests that simultaneous observations of acoustic and electromagnetic transmissions in the atmosphere may yield useful information about its composition at any given time and place.

Horace M. Trent, USA

Ballistics, Detonics (Explosions)

(See Rev. 4673)

Soil Mechanics, Seepage

(See also Revs. 4611, 4612)

4646. Jelinek, R., Effect of the foundation depth and limited layer thickness on the pressure distribution in foundation soil (in German), *Bautechnik* **28,** 6, 125–130, June 1951.

According to author's opinion, the great differences generally observed between calculated and measured settlements of foundations are due to two main causes: (1) The usual formulas for the evaluation of settlements are based on the hypothesis of forces acting on the horizontal surface of a semi-infinite elastic mass, while in reality the foundation acts as a force at a certain depth of the surface. (2) The semi-infinite mass is considered of infinite depth and in reality it is limited by the thickness of the layers.

In order to establish the real distribution of stress, author makes use of the studies developed by Melan and Mindlin for a force acting in the interior of the semi-infinite mass and of those of Marguerre and Prasser for the influence of a limited depth of the mass.

As development of the calculus leads to very complicated formulas, an approximate method is given and a "reduced depth" is introduced, which allows a rapid and easy evaluation of the stress distribution. Application is made for usual forms of foundations, and graphs are given to show the corrections which must be introduced in the usual methods of calculation.

Aurel A. Beleş, Rumania

4647. Mogaray, A., Behaviour of pier blocks founded in alluvial deposits of non-cohesive soil of infinite depth (in French), *Ann. Ponts Chauss.* **121,** 2, 133–166, Mar.-Apr. 1951.

Some of the spans of the Lyon arch bridges were destroyed during World War II, while others have remained intact. This caused slow horizontal movements of adjacent piers, resulting in an increase of the earth pressure against these piers on the passive side. In the reconstruction, the piers were moved back for some distance by hydraulic jacks. No vertical movements of the piers were observed, from which the author concludes that the foundation pressures of the piers were not increased by the destruction. Calculations are given to prove this point of view.

F. C. de Nie, Holland

4648. Stötzner, O., Contribution to the calculation of the foundations of transmission towers taking into account the soil elasticity (in German), *Bautechnik* **28,** 7, 84–88, July 1951.

In first part of paper the horizontal earth pressure p on a foundation in the form of a vertical pole is calculated under the suppositions that local earth resistance is proportional to depth below surface and to displacement of foundation. For a rigid pole, p will be distributed according to a parabolic law; p_{max} and the center of rotation of the pole may be calculated from equilibrium conditions. Generalization follows to rigid foundation blocks of rectangular and other cross sections, where position of center of rotation also may be derived from above assumptions. Author recommends local experimental determination of p_{max} for the earth as a basis for design calculations. The angle of rotation of foundation should be kept within limits set by experience.

Folke K. G. Odqvist, Sweden

4649. Kufarev, P. P., Problem of the oil-bearing contour for a circle with an arbitrary number of sinks (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **75,** 4, 507–510, Dec. 1950.

Oil occupies the region $G(0)$ at time $t = 0$, and is removed through sinks with variable strengths, $q_k(t)$. The complex potential of the flow is found, essentially by a conformal mapping, with a view toward finding shrinkage of the region $G(0)$. A short illustration is given.

R. E. Gaskell, USA

4650. Haefeli, R., Investigation and measurements of the shear strengths of saturated cohesive soils, *Géotechnique Lond.* 2, 3, 186–208, June 1951.

Tests on saturated clay, using both the ring shear and the triaxial testing machines, have been used as a basis for a discussion of the theories regarding the shearing strength of clay. Paper includes discussions on the fundamental relationships between shearing strength and consolidation pressure, shearing strength

and water content, the change in consolidation and water content occurring during slow shear tests in an open or drained system, the shearing strength in a closed system with pore-water pressure, the shearing strength of relieved material, and residual shearing stress. Variations between test results and theory are shown.

An application of the theory to the determination of the stability of an earth dam is presented to illustrate the theory of creep before failure and progressive failure. The introduction of the residual shear stress makes it possible to estimate the stability for progressive failure.

Paper is clearly presented and well illustrated.

Frederick J. Converse, USA

4651. Kirkham, D., Seepage into drain tubes in stratified soil, *Trans. Amer. geophys. Un.* **32,** 3, 422–442, June 1951.

Flow nets are derived for surface water seeping into drains embedded in either one of two adjacent horizontal water-saturated soil strata of different permeabilities. It is shown how Kennelley's tables of the complex hyperbolic sine are used to obtain numerical values for equipotentials and streamlines simultaneously. Mathematical analysis is presented in detail, but a reader not desiring to follow the mathematics may skip its development without loss of continuity. John C. Geyer, USA

4652. Mayer, A., Measurement of shear strength in French laboratories (in French), *Géotechnique Lond.* **2,** 3, 236–243, June 1951.

Author reviews the methods used in French laboratories for measuring soil shear strength and in particular describes (1) tests devised for the purpose of determining factors which affect shear strength, (2) the difference between rapid and slow shear tests, (3) the relationship between consolidation pressure and cohesion of remolded soils, and (4) a device which allows the range of vertical and transverse pressures to be inverted in the triaxial test. It is stated that surface pressure of pore liquid has no practical influence on cohesion.

From author's summary by E. Vey, USA

4653. Habib, P., and Marchand, M. R., Simple shear tests (in French) *Ann. Inst. tech. Bât. Trav. publics (N.S.)* no. 195, 14 pp., June 1951.

Authors describe shear tests commonly carried out in soil mechanics laboratories with stress-control and strain-control machines. Investigations are described of some points affecting the results: box dimensions (similar results obtained as the dimension differed only slightly), speed of deformation (shear strength of sands independent of speed).

Authors emphasize some points of error during test: time of consolidation, friction of soil on metal, rocking motion of shear box, and others. The effect of these factors may be evaluated using the stress-deformation curves. Authors suggest the use of constant-speed machine since it provides a maximum and minimum value for shear strength. Árpád Kézdi, Hungary

4654. Croney, D., Coleman, J. D., and Currer, E. W. H., The electrical resistance method of measuring soil moisture, *Brit. J. app. Phys.* **2,** 4, 85–91, Apr. 1951.

Gages of absorbent material $^5/_{16}$-in. diam and $1^1/_4$ in. long containing concentric electrodes are described. Methods and data are presented showing the relation between suction of water in absorbent material (alumina cement or plaster of Paris) and moisture content, moisture content of absorbent material and electrical resistance of gage, and suction of water in soil (undisturbed clays) and its moisture content. These relationships and derived combinations showed considerable hysteresis. Effect of temperature on resistance was proportional to viscosity of water. The gages were not sensitive for suctions of less than 10 feet of water. Edward S. Barber, USA

4655. Citrini, D., Drainage by channels and systems of wells in an artesian stratum (in Italian), *Energia elett.* **28,** 1, 1–12 Jan. 1951.

Author studies the flow of homogeneous fluids through an artesian horizontal stratum with a system of radial vertical clefts, and researches into the complex potential of this motion. (The radial clefts present a symmetrical distribution.) He then compares this motion with the flow in the same stratum with a vertical well and with different vertical wells disposed at the summits of a regular polygon (solution by approximation).

L. J. Tison, Belgium

4656. Miller, F. G., Steady flow of two-phase single-component fluids through porous media, *J. Petr. Technol. Trans.* **3** (192), 7, 205–216, July 1951.

Author considers problem of pressure distribution and weight rate associated with macroscopically linear flow of a gas-liquid, one-component mixture through a porous medium. Problem is important where fluids boil in porous media and, particularly, in oil-well production.

Steady-state, adiabatic, isenthalpic process with phase equilibrium is assumed. At a given cross section, weight fraction of gas present proved different from weight fraction flowing. O'Brien and Putnam theory [*AIME T.P.* 1349, *Petr. Technol.*, July 1941] is modified accordingly, and equations are developed for pressures and flow rates. Interfacial curvature-surface tension-pressure differences proved negligible. Wykoff and Botsett [*Physics* **7,** 9, 325–345, Sept. 1936] unconsolidated sand relative permeabilities are used to evaluate pressure-flow-rate integrals encountered in analysis. Sample calculations given.

Theoretical conditions were simulated experimentally by circulating propane through a 2-in.-diam packed-sand column, 5 ft long, fitted with pressure taps and thermocouples. Liquid from pump was heated, forced through column where it was partly evaporated, condensed, metered, and returned to pump. Pressure and volume were controlled by nitrogen-loaded accumulators. Adiabatic conditions were approximated by matching temperatures in sand with air-bath temperatures outside. Homogeneous fluid permeability of sand was approximately one darcy. Ranges of pressures, temperatures, and flow rates were 134 to 211 psi absolute, 76 to 108 F, and 7 to 14 lb per hr, respectively. Theoretical and experimental pressure distributions and weight rates checked well within experimental error.

Reviewer believes results are important in study of oil production. Experimental evidence of phase equilibrium has thermodynamic interest. Alan D. K. Laird, USA

Geophysics, Meteorology, Oceanography

(See also Revs. 4510, 4560, 4645)

4657. Munk, W. H., and Palmén, E., Note on the dynamics of the Antarctic circumpolar current, *Tellus* **3,** 1, 53–55, Feb. 1951.

Because the Antarctic circumpolar current does not have the meridional boundaries common to other ocean currents, intense western currents do not appear in the solution of the purely wind-driven theory; hence, the dissipative mechanism is so weak that computed transports are 500 times the observed. Paper suggests that a weak meridional circulation may extend the current deep enough to bring bottom stresses over submarine ridges into play.

Reviewer suggests that some other agency (e.g., secondary thermohaline circulation) could cause sufficient concentration of surface transport lines to provide dissipative mechanism without requiring deep extension of current. Henry Stommel, USA

4658. Pardé, M., Potamology [Potamologic], 2 vols., 2nd ed. (in French), Grenoble, Univ. Grenoble, 1949, 336 pp.

This excellent textbook on river hydrology treats regime of the surface runoff in the entire world. Part 1 contains topography, hydrologic climatology, and nature of soils. Part 2 deals with hydrometric measurements and calculations: water stage, discharge formulas, gagings, discharge curve. Part 3 represents elements of regime: monthly variations, average annual abundance, most significant and low discharges, floods, prognose of discharges. Book is a very valuable development of the well-known book by the same author, "Fleuves et rivières" [2nd ed., Paris, Armand Colin, 1947]. Both are worthy of being published in English. Steponas Kolupaila, USA

4659. Hassanein, S. A. M., A wave pattern changing with time as a solution of the vorticity equation for non-divergent motion, *Tellus* **1,** 4, 58–60, 1949.

The author studies the vorticity equation obtained by Rossby [*J. Mar. Res.* **2,** 38–55, 1939] to describe the horizontal motion of the earth's atmosphere, assumed to be a homogeneous inviscid incompressible fluid. He obtains a special solution which includes as a special case others given by Rossby [loc. cit.], Haurwitz [ibid. **3,** 35–50, 1940] and Machta [*J. Meteor.* **6,** 261–265, 1949], discusses the nature of the disturbances described by it, and shows that both amplified waves and damped waves are possible.

C. Truesdell, USA

4660. Yeh, T. C., On the maintenance of zonal circulation in the atmosphere, *J. Meteor.* **8,** 3, 146–150, June 1951.

Vertical component of cyclonic vorticity relative to earth is gained or lost by atmosphere through skin friction when it is negative or positive, respectively. Without any knowledge of the rate of gain or loss, author concludes that equatorial easterlies *must* be accompanied by transfer of vorticity across equator southward.

Using rectangular Cartesian coordinates, he integrates the rate of change of this vorticity component over a spherical polar cap to determine the rate of transfer across a latitude! With a faulty coordinate system, truth of conclusions is fortuitous. Local changes in density are ignored on grounds that they do not affect rates of transfer by advection, and then theory is applied to observations of the atmosphere where vorticity is created by local density changes.

Author cannot understand terms giving advection of vorticity in shearing air due to flow inclined to the horizontal, and discards them because "they cannot be computed from our present knowledge." Obviously, they might be very important since gravity creates vorticity through inclined motion.

After admitting that knowledge necessary to calculate the rate of replacement by a meridional circulation of vorticity lost by friction is "not likely to be available in the near future," he proceeds to make the calculations. Statement that "in view of assumptions made and data used, tables 2 and 3 can be considered accurate only to a rough order of magnitude" is a gross understatement. The main conclusion is that vorticity transfers by geostrophic wind and by mean meridional wind are in the same direction and same order of magnitude in low latitudes, but the former is greater outside the tropics. The relevance of this to the maintenance of the zonal circulation cannot be assessed in absence of discussion of generation of vorticity by baroclinic processes.

Premature dynamical estimates of this kind are fashionable nowadays and, though often stimulating, ignore the physics of the circulation of the atmosphere and are very academic.

R. S. Scorer, USA

4661. Rider, N. E., and Robinson, G. D., A study of the transfer of heat and water vapour above a surface of short grass, *Quart. J. roy. meteor. Soc.* **77,** 333, 375–401, July 1951.

Equality or otherwise of the eddy exchange coefficients of heat K_h, water vapor K_v, and momentum K_m in the lowest meter of the atmosphere is examined in the light of detailed profiles and heat-balance measurements over a short grass surface.

Equality of the coefficients, suggested by similarity of the vertical profiles of the various entities, is found generally to be supported by agreement between the turbulent fluxes of heat and water vapor computed by two distinct methods: (*a*) Heat-balance method using the Bowen ratio assumption of $K_h = K_v$; (*b*) "aerodynamic method" assuming $K_h = K_v = K_m$, the value of the last being obtained from the wind-velocity profiles using established aerodynamic results.

The results of this work, in which the radiation measurements received unusually adequate attention, disagree with those of Pasquill [*Proc. roy. Soc. Lond. Ser. A*, **198,** 116, 1949] who, however, measured evaporation by the soil-pot technique and so obtained K_v more directly. Under unstable conditions Pasquill found K_h to be about twice K_v. Reviewer suggests both results should be accepted with reserve owing to the rather large errors likely to attend the estimation of convective heat flux as a residual in a heat budget involving six other heat quantities, all of similar or greater magnitude. E. L. Deacon, Australia

4662. Bowen, E. G., and Davidson, K. A., A raindrop spectrograph, *Quart. J. roy. meteor. Soc.* **77,** 333, 445–449, July 1951.

A simple form of raindrop spectrograph is described. It is capable of giving a continuous record of the changes in the distribution of drop sizes which occur during a fall of rain. Examples are given of the spectra obtained during a variety of rain situations ranging from continuous rain to isolated showers.

From authors' summary

4663. Sanford, E. R., A wind-tunnel investigation of the limitations of thermistor anemometry, *J. Meteor.* **8,** 3, 182–190, June 1951.

For meteorological turbulence studies, for which the usual forms of hot-wire anemometer are not well adapted, the use of thermistors operated on similar principles is attractive owing to their very large temperature coefficient of resistance and greater robustness. Author finds a bead thermistor can be arranged to have a time constant small enough (40 m sec) for meteorological turbulence work, and sensitivity maintained sufficiently at high wind speeds for use up to 60 mph. Lack of symmetry of commercially available thermistor beads caused rather large variations of sensitivity with wind direction which have not been eliminated. Thermistor anemometers should have engineering application in problems where direction effect is not important but requires a sensing element of small size and/or relatively quick response.

E. L. Deacon, Australia

4664. Sheppard, P. A., and Elnesr, M. K., On the direct measurement of humidity mixing ratio and its fluctuations, *Quart. J. roy. meteor. Soc.* **77,** 333, 450–455, July 1951.

An apparatus is described for the direct measurement of humidity mixing ratio. It is designed primarily for recording the turbulent fluctuations in the mixing ratio in the lower atmosphere, and is based on an electrical analog of the wet-bulb equation.

using dry- and wet-bulb thermocouples. Field tests give agreement with Assmann psychrometer values to within less than 1% under conditions favorable for comparison.

From authors' summary

Lubrication; Bearings; Wear

4665. Oberle, T. L., Properties influencing wear of metals, *J. Metals* **3,** 6, 438–439G, June 1951.

Paper deals with a practical measure of wear resistance of metals: M = Brinell hardness $\times 10^6$/elastic modulus. M gives an indication of the depth of penetration that a material can tolerate without exceeding its elastic limit. Materials of high M behave like a spring, absorbing energy and preventing loads from building up to a high value.

The utility of the use of M is established fully by many results of experiments by different authors. Methods of increasing hardness are well explored; great gains appear in the direction of lowering the elastic modulus of materials. The development of improved wear-resistant materials would be accelerated by the development of a simple indentation type of test for measuring the elastic modulus of surfaces. Hans Drescher, Germany

4666. Macks, E. F., and Nemeth, Z. N., Investigation of 75-mm-bore cylindrical-roller bearings at high speeds. III. Lubrication and cooling studies—oil-inlet distribution, oil-inlet temperature, and generalized single-oil jet cooling-correlation analysis, *Nat. adv. Comm. Aero. tech. Note* 2420, 49 pp., July 1951.

Results of an experimental investigation of the effect of oil-inlet distribution and oil-inlet temperature on the inner- and outer-race temperatures of 75-mm-bore (size 215) cylindrical-roller inner-race-riding cage-type bearings are reported. A radial-load test rig was used over a range of DN values (product of the bearing bore in mm and the shaft speed in rpm) from 0.3×10^6 to 1.2×10^6 and static radial loads from 7 to 1113 lb. Oil-inlet distribution was found to be an important factor in the lubrication and cooling effectiveness of a given quantity of oil. Oil supplied by multiple jets (nonopposed) produced appreciably lower inner-race temperatures, outer-race temperatures, and outer-race circumferential temperature gradients at a given oil flow than did oil supplied by a single-jet, single-opposed-jet, multiple-opposed-jet, or outer-race-hole distribution. Oil supplied by single-opposed jets produced lower inner-race and outer-race bearing temperatures at a given oil flow than did oil supplied by a single jet, particularly at low oil flows. Inner- and outer-race temperatures decreased from 0.5° to 1° for each 1 F decrease in oil-inlet temperature over the range of oil-inlet temperatures from 100 to 205 F; the exact decrease depended upon the particular operating condition. It is possible to generalize the test-rig results for single-jet lubrication so that the inner-race or the outer-race bearing temperatures may be predicted from a single curve regardless of whether speed, load, oil flow, oil-inlet temperature, oil-inlet viscosity as affected by oil-inlet temperature, oil-jet diameter, or any combination of these parameters is varied. From authors' summary

4667. Burwell, J. T., Recent developments in full fluid lubrication, *Annals N. Y. Acad. Sci.* **53,** 759–778, June 1951.

Paper reviews main contributions to theory of hydrodynamic bearings appearing during past ten years. Comparison of calculations relating eccentricity with "nondimensional load" published by Muskat and Morgan with those of Cameron and Wood shows lack of agreement, and author recommends application of former to eccentricities below 0.5 and latter when the value is higher.

Bearings under dynamic loading are discussed and attention drawn to the paradox that connecting-rod bearings in four cycle engines run much more satisfactorily than theory would indicate. Taylor vortexes, Fogg's bearing, and hydrostatic lubrication are referred to, and analysis of a bearing based on the inertia of the lubricant indicates a load capacity which is disappointingly low.

Regarding calculation of bearing temperatures, author infers from more precise treatment of single case by Christopherson that the data of Muscat and Morgan, Cameron and Wood, and Waters may be relied upon. He shows that bearing design must be based on two criteria, film thickness and temperature rise. Reviewer feels that paper demonstrates complexity of problem and approximate nature of theoretical treatments so far advanced, and shows that the problem of placing design of bearings on a strictly rational basis still awaits solution. F. T. Barwell, Scotland

4668. Archibald, F. R., A simple hydrodynamic thrust bearing, *Trans. Amer. Soc. mech. Engrs.* **72,** 393–400, 1950.

The analysis of a slider bearing with a stepped oil film is carried out, taking into account the side leakage. The bearings considered are of rectangular and sectorial shape. The results are compared with the classical (no side leakage) results.

G. F. Carrier, USA

4669. Bradbury, D., Mark, M., and Kleinschmidt, R. V., Viscosity and density of lubricating oils from 0 to 150,000 psig and 32 to 425 F, *Trans. Amer. Soc. mech. Engrs.* **73,** 5, 667–672, July 1951.

4670. Chien, W.-Z., Hydrodynamic theory of lubrication for plane sliders of finite width, *Chin. J. Phys.* **7,** 278–299, 1949.

The incompressible viscous fluid motion associated with this film lubrication is studied. The solution (velocity and pressure) of the Navier-Stokes equations is represented as a power series in the film-thickness coordinates. The zeroth-order problem arising from this expansion is then treated by a perturbation in the thickness itself. The lowest-order perturbation appears as the solution of the classical Reynolds problem. This problem is formulated as a variational problem whose direct solution, in certain examples, checks well with a more precise integration of the Reynolds equations. G. F. Carrier, USA

4671. Wang, T.-T., Theory of hydrodynamic lubrication of plane slider and full journal bearing with side leakage (in Chinese), *Engng. Rep. nat. Tsing Hua Univ.* **4,** 2, 96–106, 1950.

Author has calculated approximately the pressure and skin-friction coefficients for the cases of plane slider and full-journal bearings with side leakage by the Rayleigh-Ritz method. Previously, W.-Z. Chien [see preceding review] has shown that in the theory of lubrication the solution of Reynolds equation can be replaced by a variational problem. Y. H. Kuo, USA

4672. Schnurmann, R., Mechanical methods of testing lubricants, *Instrum. Measur. Conf. Stockholm, Trans.*, 154–164, 1949.

This is a review covering some work of the author and other workers in the fields of non-Newtonian fluid flow and the friction of solids under conditions of boundary lubrication.

Temporary and permanent reductions in viscosity of fluids under high rates of shear are discussed and a technique for capillary-type measurements of viscosity is presented which permits high shearing stress with laminar flow and negligible viscous heating of the fluid.

It is emphasized that in boundary friction the "coefficient of friction" is not fixed by a choice of rubbing materials and lubri-

cant but is a function of a number of operating conditions such as load, sliding velocity, and temperature. These factors and the relationship between wear and normal load are discussed at length, the arguments being supported by data obtained on a four-ball apparatus. It is concluded that a number of boundary lubricants can be rated by measuring the friction force as a function of normal load, or when Amonton's law is known to be valid for a given load range, by observing wear rate as a function of normal load. Charles D. Strang, USA

✎4673. **Bowden, F. P., and Tabor, D., The friction and lubrication of solids,** Oxford, Clarendon Press, 1950, xii + 337 pp. 87.

Monograph presents the major findings of the authors and their associates in the Laboratory on the Physics and Chemistry of Solids at Cambridge University, England, and covers a period of research of approximately fifteen years. The text is extremely well written and illustrated.

Subject matter treated is primarily for surfaces in full or partial metallic contact, little space being devoted to the hydrodynamical aspects of lubrication; consequently, the text is essentially nonmathematical. Many beautifully designed experiments of unusual simplicity are used to establish key concepts associated with such topics as: the real area of contact between solids, the surface temperature of sliding surfaces, the nature of polishing, the physical nature of metallic and nonmetallic friction, the role of the contaminating film, and the boundary friction of lubricated surfaces.

Topics are included that might not be expected to be found in a work of this sort. These include a treatment of the nature of contact between colliding solids, and a discussion of chemical reactions produced by friction and impact. The manner in which explosives decompose is considered as part of this latter material.

Being essentially a monograph, the book follows closely the researches of the authors. As a result, the coverage is not well balanced on the basis of modern textbook standards. The space allotted to dry friction and its causes far outweighs that assigned to wear phenomena and the chemical aspects of boundary lubrication. However, the monograph approach makes it possible to gain the reader's confidence and provides very stimulating reading. This book will be invaluable to those doing research in the field of boundary friction and related topics, and will exert a major influence in the thinking in these areas for many years to come.

Milton C. Shaw, USA

4674. **Gould, G. G., Determination of the dynamic coefficient of friction for transient conditions,** *Trans. Amer. Soc. mech. Engrs.* **73,** 5, 649–654, July 1951.

Friction of some typical friction-clutch and brake materials was measured as a function of the time after starting. Friction was found to vary during first few minutes of operation (after complete run-in) under constant speed and pressure, presumably due to changes in surface temperature and film formation. Author draws obvious conclusion that under such conditions a characteristic value of friction coefficient for the given pair of materials cannot be assigned. John T. Burwell, Jr., USA

4675. **Bowden, F. P., The influence of surface films on the friction, adhesion, and surface damage of solids,** *Annals N. Y. Acad. Sci.* **53,** 805–823, June 1951.

A review and extension of work by Bowden and associates on the role of surface films. Friction of outgassed materials and surfaces exposed to contamination by a variety of substances is discussed. The performance of some lubricant additives is explained by these observations. Work on friction and adhesion between steel and indium lends further support to the "welded-junction" theory of friction. Joseph B. Bidwell, USA

Marine Engineering Problems

(See also Rev. 4400)

4676. **Crenn, R., Calculation of stability after sea-damage** (in French), *Bull. Assn. tech. marit. aéro.* no. 49, 535–563, 1950.

Convention of London (1948) specified allowable safe metacentric height and heel after ship is damaged by flooding of one or more compartments; also ruled that the captain be given information necessary to tell whether intact ship and load would remain within these limits after damage. Present paper suggests this information be curves of maximum allowable height of center of gravity (for intact loaded ship) vs. displacement, with trim as parameter; if loading is such that height of actual center of gravity does not exceed this curve, London rules are obeyed. Modifications for one or more compartments empty are included by showing least favorable case. Bulk of paper shows how to compute such curves for given ship, loading, and type of damage, and justifies sufficiency of these curves. Various useful approximations are outlined. Method applies particularly to freighters, though brief comments on passenger ships are included.

A. O. Williams, Jr., USA

4677. **Cook, R., Marine torsionmeters and thrustmeters,** *Trans. Inst. mar. Engrs.* **63,** 7, 115–131, July 1951.

The general requirements of torsion meters and thrust meters for marine use are discussed first, together with some of the fundamental difficulties encountered in their design. A critical survey is then made of the various forms of torsion meter which have been used or proposed for marine use, and results are given of experimental investigations into the degree of accuracy obtainable with the Siemens-Ford torsion meter. It is concluded that this instrument is capable of an accuracy of at least $\pm 2\%$ over a range of shaft stress from about 2500 psi to 4500 psi, this range covering the full power condition in most merchant ships. In vessels with Diesel machinery aft, the full power stresses are frequently lower, and in these cases somewhat less accurate results are to be expected.

A similar survey is made in respect to thrust meters and the results are given of calibration trials with a Michell thrust meter from which it is concluded that an accuracy of at least $\pm 2\%$ is obtainable with this instrument under full power conditions.

From author's summary

Please Note

The Subject and Author Indexes to APPLIED MECHANICS REVIEWS, Vol. 4, January-December, 1951, are to be published in separate pamphlet form and will be mailed together with the January, 1952, issue of APPLIED MECHANICS REVIEWS.

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE *(Continued)*

Pöschl, Th. 4429
Prager, W. 4444
Prentis, J. M. 4437
Prian, V. D. 4583
Rawson, H. 4486
Reichardt, H. 4549
Reissner, E. 4410
Renouard, M. 4476
Ricci, L. 4367
Richter, H. 4495
Rider, N. E. 4661
Riegels, F. 4594
Rivlin, R. S. 4404
Robb, W. L. 4614
Robinson, A. 4520
Robinson, G. D. 4661
Ros, M. 4440
Rosenbaum, R. 4574
Rosenberg, R. M. 4395
Rossen, J. N. 4463
Rossow, V. J. 4539
Rott, N. 4568
Rowlinson, J. S. 4637
Rubinshtein, L. I. 4627
Runyan, H. L. 4575
Russell, W. R. 4596
Sag, N. 4398
Sakurai, A. 4552
Sanford, E. R. 4663
Sarkaria, G. S. 4434
Sauer, F. M. 4541
Scanlan, R. H. 4574
Schade, Th. 4415
Schaub, C. 4488
Scherrer, R. 4543
Schlichting, H. 4566
Schmeidler, W. 4362
Schmidt, E. 4605
Schneider, W. G. 4632
Schnurmann, R. 4672
Schürch, H. 4418, 4419
Seacord, C. L., Jr. 4572
Seeger, R. J. 4519
Sestini, G. 4624
Severn, R. T. 4628
Shapiro, A. H. 4522
Sheppard, P. A. 4664
Shu, S. S. 4518
Shufflebarger, C. C. 4559
Sills, E. C. 4505
Sleeswijk, A. W. 4581
Smelt, R. 4578
Smith, F. 4578
Soete, W. 4427
Spence, A. 4556
Stalder, J. R. 4613
Stanitz, J. D. 4583
Stearns, R. F. 4599
Stein, M. 4410
Steinicke, H. 4605
Stine, H. A. 4535
Stoever, H. J. 4602
Stoppelli, F. 4377
Stötzner, O. 4648
Strawbridge, D. J. 4451
Suquet, F. 4501
Sykes, A. O. 4386
Szelagowski, F. F. 4397
Tabor, D. 4673
Taylor, B. L., III 4587
Taylor, N. W. 4464
Teofilato, P. 4531
Thielsch, H. 4487
Thomas, A. G. 4404
Thompson, J. S. 4578
Thorpe, T. C. G. 4482
Tifford, A. N. 4551
Timman, R. 4503
Timofeeva, M. N. 4446
Tishin, M. M. 4382
Toms, B. A. 4451
Tordai, L. 4609
Traustel, S. 4496, 4631
Trilling, L. 4508
Trollope, D. H. 4569
Trout, A. M. 4586
Truitt, R. W. 4528
Uzhik, G. V. 4457
Vallance, A. 4396
Vallander, S. V. 4538, 4623
Vallette, R. 4441
VanCrombrugge, R. 4427
van der Eb, W. J. 4417
Van Dyke, M. D. 4540
van Heemert, A. 4565
Vasarhelyi, D. 4442
Vietoris, L. 4389
Vigoureux, P. 4639
Vincenti, W. G. 4530
Volkov, S. D. 4445
von Kármán, T. 4554
Vreede, F. A. 4413
Wagoner, C. B. 4530
Wang, T.-T. 4671
Wattendorf, F. L. 4584
Wax, N. 4390
Weil, H. 4545
Weiner, J. H. 4615
Weininger, J. L. 4632
Weirich, H. 4490
Wells, A. A. 4358
Wells, C. P. 4406
Westerdijk, J. B. 4597
Westervelt, P. J. 4642
White, A. E. 4465
Wilcox, E. C. 4586
Wilder, A. B. 4426
Wilkes, G. B., Jr. 4459
Williams, D. 4432
Wintner, A. 4507
Woersching, T. B. 4532
Wolansky, J. 4551
Woolston, D. S. 4575
Woodward, F. A. 4563
Yang, H. T. 4433
Yeh, T. C. 4660
Yokobori, T. 4472
Young, A. D. 4542
Zaat, J. A. 4546
Zeldovich, Y. B. 4604
Zeuli, T. 4384
Ziegler, N. A. 4485
Zmuda, A. J. 4641
Zurick, V. J. 4613
Zurmühl, R. 4361

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE

(NUMBERS USED ARE SERIAL NUMBERS OF REVIEWS)

Adams, C. H. 4469
Akulov, N. S. 4458
Allen, D. N. de G. 4628
Anastasi, A. 4577
Andersen, F. 4477
Anthony, M. L. 4626
Aquaro, G. 4399
Archibald, F. R. 4668
Arnoldi, W. E. 4373
Assadourian, A. 4557
Babbitt, J. D. 4610
Babister, A. W. 4505
Balaca, A. P. 4359
Baldacci, R. F. 4430
Barry, F. W. 4522
Beer, H. 4438
Behrbohm, H. 4516
Bellenot, Ch. 4387
Bennett, J. B. 4589
Bereis, R. 4376
Bergeron, P. 4499
Berman, R. 4630
Bers, L. 4529
Beth, R. A. 4406
Biésel, F. 4501
Birebent, A. 4478
Bishop, S. M. 4470, 4471
Bisplinghoff, R. L. 4365
Blackaby, J. R. 4523
Boelter, L. M. K. 4598
Bošnjakovic, F. 4618
Bosshard, E. 4435
Boué, P. 4428
Bowden, F. P. 4673, 4675
Bowen, E. G. 4662
Boyer, R. F. 4456
Brace, P. H. 4485
Bradbury, D. 4669
Bright, P. 4592
Broughton, G. 4616
Brown, E. H. 4421
Brown, W. F. 4517
Bubb, F. W. 4370, 4371
Bundgaard, S. 4379
Bursnall, W. J. 4544
Burwell, J. T. 4667
Cahen, G. 4388
Cahn, R. W. 4449
Callan, M. M. 4506
Campbell, J. P. 4555
Carman, P. C. 4611, 4612
Casci, C. 4620
Chang, C.-C. 4514
Chaplígin, S. A. 4567
Charles, H. 4392, 4622
Cherry, T. M. 4533
Chien, W.-Z. 4670
Citrini, D. 4655
Closmann, P. J. 4463
Cole, J. D. 4527
Coleman, J. D. 4654
Contensou, P. 4571
Conway, H. D. 4411
Cook, R. 4677
Corlett, E. C. B. 4400
Corrsin, S. 4553
Crede, C. E. 4385
Crenn, R. 4676
Croney, D. 4654
Crouch, F. W. 4426
Cuff, G. 4466
Currer, E. W. H. 4654
Dahlquist, C. A. 4464
Davidenkov, N. N. 4446
Davidson, K. A. 4662
Davis, H. 4590
Davis, J. A. 4484
Davison, B. 4578
Deards, S. R. 4505
Deublein, O. 4494
Diederich, F. W. 4564
Dietz, A. G. H. 4463
Dillon, J. H. 4480
Donely, Ph. 4560
Doughtie, V. L. 4396
Drickamer, H. G. 4614
Dumas, M. 4360
Dunell, B. A. 4480
Durand, H. P. 4395
Earley, J. W. 4636
Eastwood, L. W. 4483, 4484
Eckart, G. 4645
Eckert, E. R. G. 4619
Elnesr, M. K. 4664
Elovskikh, M. P. 4623
Erdmann, S. F. 4595
Erythropel, H. 4493
Escande, L. 4489
Etkin, B. 4563
Eujen, E. 4600
Eustis, R. H. 4558
Farber, E. A. 4629
Fastov, N. S. 4452
Faupel, J. H. 4467
Fay, R. D. 4643
Federhofer, K. 4375
Fel'dshtein, Ya. I. 4458
Fenn, J. B. 4606
Finch, R. B. 4479
Fischer, O. F. 4364
Flake, G. 4366
Fogagnolo Massaglia, B. 4378
Forney, H. B. 4606
Fortier, O. V. 4643
Freeman, J. W. 4465
Frey, D. N. 4465, 4468
Garmon, R. C. 4606
Gerard, G. 4409
Germans, F. H. 4481
Gifkins, R. C. 4455
Gilmour, A. 4633
Ginsburg, A. 4585
Golitzine, N. 4510
Gol'denveizer, A. L. 4412
Goldstein, A. W. 4515
Goran, L. A. 4420
Gould, G. G. 4674
Gracey, W. 4596
Graham, E. W. 4513
Green, V. L. 4436
Gross, D. 4615
Grover, H. J. 4470, 4471
Grube, K. 4483, 4484
Gursahaney, H. J. 4416
Haacke, W. 4380
Habib, P. 4653
Haefeli, R. 4650
Hardway, E. V., Jr. 4601
Hardy, H. K. 4474
Haringx, J. A. 4423, 4424
Harrison, M. 4386
Hartree, D. R. 4357
Haskind, M. D. 4394
Hassanein, S. A. M. 4659
Hausenblas, H. 4579
Head, J. W. 4368
Heald, W. R. 4422
Hechtman, R. A. 4442
Heisenberg, W. 4547
Hendricks, J. O. 4464
Henry, J. R. 4589
Herni, H. 4372
Higgins, R. W. 4534
Himmel, S. C. 4580
Hodge, P. G., Jr. 4444
Hopkins, H. G. 4421
Howard, D. A. 4570
Howarth, L. 4537
Hsu, E.-Y. 4504
Hu, L. W. 4467
Ingard, U. 4640
Inglis, Sir C. 4374
Jackson, L. R. 4470, 4471
Jackson, R. M. 4599
Jaeckel, K. 4363
Jaumotte, A. 4498
Jelinek, R. 4646
Jellinghaus, W. 4635
Johnson, D. C. 4393
Johnson, J. A. 4558
Johnson, R. R. 4599
Jones, G. 4366
Jones, M. 4592
Jones, W. E., Jr. 4459
Jorissen, A. L. 4500
Jouenne, M. 4492
Kaan, J. F. 4597
Kachanov, L. M. 4408
Kats, A. M. 4369
Kaufmann, W. 4502
Kavanagh, G. M. 4463
Kawaguti, M. 4509
Kawamura, R. 4521
Kayan, C. F. 4617
Kays, W. M. 4625
Kennedy, W. B. 4426
Kerr, P. 4443
King, J. C. 4569
Kirkham, D. 4651
Klassen, J. 4634
Kleinschmidt, R. V. 4669
Klier, E. P. 4448
Klöppel, K. 4428
Kottas, H. 4590
Koval'skiĭ, B. S. 4391
Kraft, C. C., Jr. 4557
Krautkrämer, H. 4461
Krautkrämer, J. 4461
Krebs, R. P. 4580
Krzywoblocki, M. Z. 4550
Kucharski, W. 4414
Kufarev, P. P. 4649
Kutateladze, S. S. 4621
Laitone, E. V. 4525, 4526
Lalive d'Epinay, J. 4387
Lambert, J. D. 4637
Lapin, E. 4573
Larson, C. A. 4599
Larson, H. 4448
Laurent, P.-H. 4475
Leclerc, A. 4491
Leslie, J. R. 4460
Letko, W. 4596
Lévi, F. 4454
Levine, H. 4644
Levy, L. I. 4365
Liepmann, H. W. 4561
Lilienthal, W. B. 4497
Lilley, G. M. 4505
Lin, C. C. 4554
Lin, T. C. 4433
Litovitz, T. A. 4638
Lockhart, R. W. 4598
Lodge, A. S. 4450
Loftin, L. K., Jr. 4544
Loitsianskiĭ, L. G. 4511
London, A. L. 4625
Longuet-Higgins, H. C. 4608
Low, G. M. 4619
Lowell, H. H. 4593
Lubkin, J. L. 4402
Luke, Y. L. 4366
Luskin, H. 4573
Macks, E. F. 4666
Macmillan, R. H. 4383
Maheu, P. 4360
Malherbe, P. leR. 4612
Marabais, L. 4473
Marchand, M. R. 4653
Marin, J. 4466, 4467
Mark, M. 4669
Markovets, M. P. 4446
Marshall, W. S. D. 4505
Martin, H. C. 4416, 4425
Matz, W. 4607
Mayer, A. 4652
Mazin, I. P. 4458
McConnell, D. 4636
McKinney, M. O. 4555
McNown, J. S. 4504
McSkimin, H. J. 4462
Melrose, J. C. 4497
Metelitsin, I. I. 4381
Michel, D. J. 4585
Miekleboro, H. C. 4559
Miles, J. W. 4524
Miller, F. G. 4656
Mizisin, J. 4585
Mock, F. C. 4588
Mogaray, A. 4647
Montag, H. 4403
Moody, A. M. G. 4590
Mooney, M. 4453
Morikawa, G. 4513
Munk, M. M. 4548
Munk, W. H. 4657
Murashev, V. I. 4439
Nagey, T. F. 4591
Naylor, C. H. 4562
Naylor, G. A. 4576
Naylor, N. 4407
Nemeth, Z. N. 4666
Nepper, M. 4473
Neubert, U. 4605
Neumann, E. P. 4522
Niles, A. S. 4431
Novozhilov, V. V. 4401
Oberle, T. L. 4665
Oding, I. A. 4447
Oguchi, H. 4521
Oldroyd, J. G. 4451
O'Rourke, R. C. 4405
Oswatitsch, K. 4516
Otto, E. W. 4587
Palmén, E. 4657
Pao, Y.-H. 4496
Pappas, C. C. 4534
Pardé, M. 4658
Paschkis, V. 4615
Penner, S. S. 4536
Peterman, H. 4582
Pian, T. H. H. 4395
Plewes, A. C. 4644
Polachek, H. 4519
Porter, A. W. 4643

(Continued on inside back cover)